Government of Nepal

Ministry of Energy, Water Resources and Irrigation

Department of Water Resources and Irrigation



Standard Specifications

For

Irrigation and River Training Works-2081

(Second Edition, Rev.1)

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Foreword



This document, **"Standard Specifications for Irrigation and River Training Works – 2081 (Second Edition, Rev.-1),"** serves as the officially updated framework succeeding the initial 2081 edition.

It has been meticulously prepared by the **Department of Water Resources and Irrigation, Planning & Co-ordination Division**. The revisions reflect extensive consultations and collaborative discussions with key stakeholders involved in water resources and river training works. By integrating the collective experience, the updated specifications ensure higher technical precision and alignment with modern engineering practices.

These specifications govern all standard construction and maintenance activities under the department's jurisdiction. For specialized engineering works not explicitly covered in this text, or for scenarios requiring technical modifications, project teams must draft **Special Specifications**. Any project-specific modifications or supplementary specifications must be formally reviewed and approved by the **competent authority** prior to project execution.

Through the rigorous implementation of these standardized guidelines, the Department of Water Resources and Irrigation aims to significantly enhance the structural quality, durability, and efficiency of water resource management and river training infrastructure across the country.

Thank you

……..

Dinesh Rajouria
Director General
DWRI

Few Words



The release of the **Standard Specifications for Irrigation and River Training Works – 2081 (Second Edition, Rev.-1)** marks a crucial step toward achieving uniformity, quality assurance, and technical rigor across all our water resource and river training projects.

As field implementations scale across diverse and dynamic hydrological landscapes, maintaining consistent quality control and adherence to standardized methodology remains our highest priority. This revised edition incorporates valuable feedback from key stakeholders, ensuring that our specifications remain adaptable to modern construction materials, environmental considerations, and site-specific engineering challenges.

I extend my sincere appreciation to the Planning and Co-ordination Division and all technical committees whose dedication and collaborative efforts brought this revision to fruition. I urge all project directors, project chiefs, site engineers, and contractors to internalize these standards and apply them diligently in the field. Constructive feedback from practical application is always welcome as we continue to refine our engineering practices for sustainable infrastructure development.

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Kushang Sherpa
Deputy Director General
Planning & Co-ordination Division, DWRI

Acknowledgement

The Department of Water Resources and Irrigation (DWRI) expresses its sincere gratitude to all past committees, individuals and institutions involved in the original version of the Standard Specifications for Irrigation and River Training Works – 2081.

For this current revision, a dedicated 13-member departmental committee was formed to review and update the technical standards. The committee comprises the following members:

- Mr. Kushang Sherpa, DDG, Planning and Co-ordination Division — Coordinator
- Mr. Ravi Shakya, SDE, Procurement and Contract Management Branch — Member
- Mr. Jebin Tamrakar, Project Chief, Large & Multipurpose Project Study & Preparation Program — Member
- Mr. Amar Bahadur Chand Thakuri, Project Manager, MIIP — Member
- Mr. Birat Gyanwali, SDE, River Management Section — Member
- Mr. Prabin Shrestha, SDE, Development Assistance & Regional Coordination Branch — Member
- Mr. Baburam Kharel, SDE(Mechanical), Mechanical Management Section — Member
- Mrs. Ezee G.C., Project Chief, IWRMP (Nuwakot) — Member
- Mrs. Yojana Neupane, SDEG., Geology & Landslide Management Section — Member
- Mr. Pramod Timalsina, SDE., System Management & Maintenance Section — Member
- Mrs. Nisha Baidar, SDE., Study, Design & Innovation Branch — Member
- Mr. Sujan Prajapati, Er., Procurement and Contract Management Branch — Member
- Mrs. Anjana Khadka, Er., Study, Design & Innovation Branch — Member
- Mrs. Rhitika Lamichane, Er., Development Assistance & Regional Coordination Branch — Member
- Mrs. Sangeeta Shahi, Er., Planning & Monitoring Branch — Supporting Colleague

A draft version of the revised specifications was circulated across all offices to gather constructive comments and recommendations from field practitioners and stakeholders. Following thorough deliberations and the careful incorporation of the feedback received, the committee finalized the document.

DWRI extends its deep appreciation to the members of the departmental committee and all contributing offices for their commitment, technical expertise, and collaborative efforts in bringing this updated edition to completion.

Acknowledgement are made to the following publications and documents which have been consulted during reviewing of these specifications for irrigation and river training works;

1. Standard Specifications For Road And Bridge Works, 2073, DoR
2. Nepal Standards
3. IS Codes
4. ASTM
5. AASHTO
6. JSCE
7. ITA Guidelines

I hope this Standard Specifications for Irrigation and River Training Works – 2081 (Second Edition, Rev.1) would be helpful to all engineers and practitioners for construction and maintenance of irrigation and river training works in Nepal. Any comments and suggestions to improve these specifications will always be appreciated.



Nisha Baidar
Branch Chief
Study, Design and Innovation Branch

STANDARD SPECIFICATIONS FOR IRRIGATION AND RIVER TRAINING WORKS

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101 INTRODUCTION

These Specifications shall be applicable to all such Irrigation and River Training works as are required to be executed as per Contract or as per instruction of the Engineer. All Works performed shall be in compliance with the alignment, lines, hydraulic levels, grades, slopes, cross-sections data, and dimensions as shown in the Drawings. If the Drawings, Special Provisions, or these Specifications state specific tolerances, then the Work shall be performed within those specified tolerances limits.

The quality of materials, processing of materials as may be needed at the site, salient features of the construction work and quality of finished work shall comply with the requirements set forth in succeeding sections. Where the drawings and Specifications describe a portion of the work in only general terms, and not in complete detail, it shall be understood that only the sound practice is to prevail, materials and workmanship of the best quality are to be employed and the instructions of the Engineer are to be fully complied.

102 DEFINITION

The words such as Contract, Contractor, Engineer/Engineer Incharge, Drawings, Employer, Government, Works and site used in this specification shall be considered to have the meaning as specified in definitions of these terms given in the General conditions of Contract.

103 SCOPE OF WORK

A. The work to be carried out under the Contract shall be generally described in the Bid Documents as well as in the Bill of Quantities furnished in the Bid Documents.

B. The works to be performed shall also include all general works preparatory to the construction of canals, irrigation structures, canal crossings, drainage, drainage structures, river training structures, tunnels and all due and satisfactory construction, completion and maintenance of works to the intent and meaning of the drawings and these specifications and further drawings and other instruction that may be issued by the Engineer from time to time.

The scope of work shall include compliance by the Contractor with all conditions of Contract whether specifically mentioned or not in the various Clauses of these Specifications, all materials, apparatus, plant, equipment, tools, fuel, water, strutting, timbering, transport, offices stores, workshop, staff, labour and the provision of proper and sufficient protective works, diversions, temporary fencing and lighting. It shall also include: safety of workers at construction site, first-aid equipment, suitable accommodation for the staff and workmen with adequate sanitary arrangements, the effecting and maintenance of all insurances, the payment of all wages, salaries, fees, royalties, duties or other charges arising out of the erection of works and the regular clearance of rubbish, reinstatement and clearing-up of the site as may be required on completion of work, safety of the public and protection of the works and adjoining land.

C. The Contractor shall ensure that all actions are taken to build in quality assurance (QA) in the planning, management and execution of works. The quality assurance shall cover all stages of work such as setting out, selection of materials, selection of construction methods, selection of equipment and plant, deployment of personnel and supervisory staff, quality control testing, etc. The Quality Assurance Plan (QAP) shall cover but not be limited only to the followings:

- Organization and management responsibility
- Document and data control
- Construction program
- Method statement
- Process control
- Working Inspection, Testing and documentary procedures
- Arrangement for smooth safe traffic flow, canal operation, water diversion and river-flow

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management during construction and maintenance

- Control and documentation of purchasing and handling of materials
- Maintenance of records for non-conformity and timely corrective actions
- Internal quality audit
- Training to staff
- Environmental Management Action Plan (EMAP)

The QAP shall be submitted to the engineer for approval not later than 28 days from the date of signing of contract agreement. Work of building in quality assurance shall be deemed to be covered in the scope of the work.

D. The Contractor shall furnish, at least 7 days in advance, unless otherwise stipulated in the contract, his program of commencement of item of work, including method for deployment of plant and equipment for the works included in the contract and any other works for which the Engineer may demand the method statement. He shall provide all information to the satisfaction of the Engineer to insure its adequacy. The sole responsibility for the safety and adequacy of the methods adopted by the contractor will, however, rest on the Contractor, irrespective of any approval given by the Engineer.

104 STANDARDS AND SUPPLEMENTAL SPECIFICATIONS

A. Wherever reference is made in these Specifications to specific standards and codes to be met by the materials, plant, and other supplies to be furnished, and work to be performed or tested, the provisions of latest current edition or revision of relevant standards and codes in effect shall apply. Other authoritative standards which ensure substantially equal or higher performance than the specified standards and codes shall be accepted subject to the Engineer's prior review and approval. Differences between the standards specified and the proposed alternative standards shall be fully described by the Contractor and submitted to the Engineer at least 28 days prior to the date when the Contractor desires the Engineer's approval. In the event that the Engineer determines that such proposed deviations do not ensure substantially performance, the Contractor shall comply with the standards and codes specified. No additional payment shall be made for adoption of higher standards.

B. Certain Specifications issued by various national or other widely recognized bodies are referred to in these Specifications. Such Specifications shall be defined and referred to as Specifications.

The Contractor may propose that the materials and workmanship be defined in accordance with the requirements of other equivalent Specifications and he may execute the works in accordance with such Specifications as may be approved by the Engineer. A copy of the Specification, together with its translation into the English language if the Specification is in another language, shall be submitted to the Engineer along with the request for its adoption.

In referring to Specifications, the following hierarchy shall be used:

(i) NS : Nepal Bureau of Standards and Metrology
(ii) IRC : Indian Road Congress (i.e. recommended Code of Practice by IRC.
(iii) IS : Indian Standards
(iv) BS : British Standards
(v) ASTM : American Society of Testing and Materials
(vi) AASHTO : American Association of State Highway and Transportation Officials.
(vii) BSCP : British Standard Code of Practice
(viii) ISO : International Organization for Standardization.
(ix) EN : European Norm

No separate payment shall be made to the Contractor for complying with this Sub-Clause.

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105 SITE INFORMATION

A. The Contractor shall erect Information boards (size: 1.8m high and 1.2m wide) at the beginning of each construction site giving details of the contract information in the format and wording as instructed by the Engineer. These boards shall be erected within 14 days after the Contractor has been given the Possession of Site.

The Contractor shall not erect any kind of advertisement on or along the information board without the prior approval of the Employer.

All information boards erected at site shall be removed by the Contractor at his own cost by the end of the Defects Liability Period.

B. Measurement and Payment

Unless stated otherwise, no separate measurement and payment shall be made for erection of information board at site as described in this Clause 110 as the cost of such works is deemed to be included in the rates of other items under BOQ.

106 SURVEY AND SETTING OUT

A. The Contractor shall resurvey the Alignment Lines, Traverse Point, and Benchmarks and confirm the co-ordinates and levels of the stations before using them for setting out the Works. He shall immediately notify the Engineer of any discrepancies and shall agree with the Engineer any amended values to be used during the contract, including replacements for any stations missing from the original stations.

B. The Contractor shall check, replace and supplement as necessary the station points and agree any revised or additional station details with the Engineer.

C. All stations and reference points shall be clearly marked and protected to the satisfaction of the Engineer.

D. Where a Station Point is likely to be disturbed during construction operations, the Contractor shall establish suitable reference stations at locations where they will not be disturbed during construction. No old station shall be covered, disturbed or destroyed until accurate reference stations have been established and details of such stations have been approved by the Engineer. The Contractor shall establish working Benchmarks tied with reference stations soon after taking possession of the site. The coordinates and the elevations of the reference stations shall be obtained from the Engineer. The working Benchmarks shall be at the rate of two per kilometer and also near all major/medium structure sites. Regular checking of these Benchmarks shall be made and adjustments, if any, got agreed with Engineer shall be recorded.

E. The Contractor shall be responsible for the accurate establishment of the centre lines based on the Drawing and data supplied. The centre lines shall be accurately referenced in a manner satisfactory to the Engineer. The reference points shall be established at every 50 m interval in plain/rolling terrain and 20 m interval in hill terrain, with marker pegs and chainage boards set in the right of way of the alignment. A schedule of reference dimensions shall be prepared and supplied by the Contractor to the Engineer.

F. The existing alignment, profile and cross-sections shall be surveyed jointly by the Engineer and the Contractor. These shall form the basis for the measurements and payments. If in the opinion of the Engineer, design modifications of the alignment/centre lines and/or slope and base levels are advisable, the Engineer shall issue detailed instructions to the Contractor and the Contractor shall perform modifications in the field, as required, and modify the levels on the cross-sections and profile accordingly.

G. Accurate control of lines and levels shall be provided by the Contractor at all stages of the construction. In respect of canals itself, control shall be at least 10 m interval or such close interval as may be directed by the Engineer. The lines and levels of canal alignment, side slope, drainage works if required, etc. shall be carefully set out and frequently checked. Care shall be taken to ensure that correct gradients and cross- sections are obtained everywhere.

H. The Contractor shall provide the Engineer with all necessary assistance for checking the setting out, agreement of levels and any other survey or measurement which the Engineer needs to carry out in

connection with the contract during the entire period of contract. Such assistance shall include:

a) Provision of suitably qualified surveyors to work under the direction of the Engineer as required.

b) Provision of all necessary support for resurvey by providing required assistant, chainmen, labours, hand tools, pegs and materials.

c) Provision of survey equipment (Precision automatic levels, theodolite, total station and distomat) as required by the Engineer for survey works

I. Measurement and Payment

No separate measurements and/or payment shall be made for the work required under this Clause. All costs incurred in connection with the work specified herein shall be considered to be included in the related items of the work in the Bill of Quantities (BOQ).

107 DRAWINGS

(1) Bidding Drawings

The drawings provided in the Bidding Documents shows the general features of the construction works. The Contractor shall prepare construction and/or shop drawings as stipulated in Sub-Clause 1.03.3 of these Specifications.

(2) Additional Drawings

The drawings attached to the Bidding Documents (hereinafter referred to as "Bidding Drawings") accompany and form part of the Contract Documents. In addition to the Bidding Drawings, Additional Drawings may be delivered by the Engineer to the Contractor and such drawings shall thereupon become part of the Contract.

During the progress of the work, Additional Drawings will be issued by the Engineer as necessity arises to supplement and/or supersede the Bidding Drawings, and such Additional Drawings shall thereupon become part of the Contract. The Contractor shall prepare construction and/or shop drawings as stipulated in Sub-Clause 1.03.3 of these Specifications.

The Contractor shall be governed by figures and dimensions as given on the drawings. Where required dimensions are not shown, the Contractor shall obtain such dimensions from the Engineer before proceeding with the construction of the portion of the Works to which they refer. In every case, detailed drawings shall take precedence of general drawings.

The Contractor shall scrutinise such drawings and such further drawings issued from time to time to the Contractor. If any ambiguity, discrepancy or mistake is found in the drawings, the same shall be referred to the Engineer before proceeding with the works, and the Engineer's decision on resolving such ambiguity, discrepancy or mistake shall be final, conclusive and binding.

(3) Drawings and Calculations to be furnished by the Contractor

Unless otherwise stated in the Contract, the Contractor shall prepare drawings for all Temporary Works to be constructed or supplied and installed by the Contractor or his Sub-Contractor.

The Bidding Drawings and the Additional Drawings delivered by the Engineer will not always be detailed enough for performance of the works. They will show many works only in typical forms supplemented by tables of dimensions. The Contractor shall at his own expense prepare detailed Construction Drawings of the individual works (hereinafter referred to as "Construction Drawings") based on the Bidding Drawings and the Additional Drawings as needed for performance of the works. All Construction Drawings prepared by the Contractor shall be submitted to the Engineer for his approval.

If required by the Engineer, the Contractor shall also submit calculations to the Engineer for his approval. The drawings submitted by the Contractor shall be clear and complete. The recommendable scales of the drawings are 1:1,000, 1:100, 1:50, 1:20, 1:10, 1:5, 1:2 or 1:1 depending upon the type of drawing and/or

details which have to be drawn. Drawings shall be of standard sizes as required by the Engineer.

In addition to the above, the Contractor shall at his own expense prepare reinforcement drawings based on the drawings supplied by the Employer/Engineer as needed for the performance of the works. These reinforcement drawings shall include such bar placing drawings, bar-bending drawings, bar list and any other reinforcement drawings as may be required to facilitate fabrication and placement of reinforcement bars. All reinforcement drawings prepared by the Contractor shall be submitted to the Engineer for his approval.

For all sections of the work to be executed under the Contract, the Contractor shall submit detailed drawings to the Engineer for his approval, including working drawings, shop drawings and specifications. The Contractor shall submit these drawings in two (2) copies to the Engineer for approval unless otherwise specified, and these drawings shall be sufficiently detailed to show:

a. The general arrangement and dimensions of all the parts and the size of each and every part of the works to be executed under the Contract.

b. The nature of the materials from which various parts are to be made, and

c. Details of all construction.

Fabrication, manufacture or construction of any part of the works shall not commence until the drawings have been approved in writing by the Engineer, and thereafter no change shall be made to any drawings so approved without permission of the Engineer. Subsequent changes shall be reported by sending another set of two (2) or specified number of copies of each revised drawing to the Engineer for approval. The approval of Contractor's drawings by the Engineer shall not relieve the Contractor from any of his liabilities or responsibilities under the Contract.

The Engineer shall check or review the drawings submitted by the Contractor and shall return them with comments or approval within twenty-eight (28) days from the date of submission by the Contractor. If re-submission of the drawings is required by the Engineer, the Contractor shall re-submit them after necessary modifications and corrections until the approval of the Engineer is obtained. In the event of disagreement with alteration, the Contractor shall send a written notice to the Engineer within 7 days after receiving the altered drawing(s).

From the approved drawings and calculations, two paper copies and one reproducible copy (in PEN DRIVE) of each set shall be submitted to the Engineer.

(4) Right to Change Design and Drawings

When additional information regarding foundation or conditions become available as a result of excavation work and further testing, and if found desirable to make changes in the alignment, cross-sections, dimensions or design to conform to such conditions, the Employer/Engineer reserves the right to make the necessary or desirable changes to the opinion of the Engineer.

(5) As-Built Drawings

The Contractor shall prepare the as-built drawings of the works actually constructed at the site. One set of all such drawings shall be kept on site and shall be marked up by the Contractor to show variations in the works.

They shall be used to maintain a record of the dimensions and other particulars of the works as they are actually constructed, as and when these particulars differ from what is shown on the approved Drawings.

These records shall be available at all reasonable times on the site for inspection and use by the Employer and by any other person authorized in writing by the Employer.

Prior to requesting a Certificate of Substantial Completion for the whole of the works, the Contractor shall provide the Employer with 1 (one) reproducible copy and 3 (three) prints of all As Built Drawings.

The drawings shall be suitable for reduction to readable A3 size and for inclusion in the operating and maintenance manuals.

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(6) Measurement and payment

No separate payment shall be made for preparation of all construction drawings, reinforcement drawings, working drawings and shop drawings, drawing details, etc., to be prepared by the Contractor and submitted to the Engineer and/or the Employer in accordance with the provisions of the Contract, except for provision of “As-Built” Drawings.

Upon the submission of required As-built Drawings and their approval by the Engineer, the cost incurred by the Contractor in compliance with the preparation of as-built drawings shall be paid as per the lump sum or unit rate for the item in the BOQ.

108 TEMPORARY DIVERSION WORKS

A. Scope

This Clause covers the construction and maintenance of necessary traffic diversions, temporary access arrangements, temporary water diversions, diversion bridge, cofferdams, channels and related protective works required for safe execution of the Works, including maintaining required river, canal, drain and watercourse flow where specified, and removal of temporary works when they become redundant.

B. General Requirements

The Contractor shall take all necessary precautions to ensure safety of road users, pedestrians, workers and the public where construction activities affect roads, paths or other public access. The Contractor shall at all times carry out works in a manner creating least interference to the flow of traffic and canal operation. Where diversion is required, the Contractor shall provide and maintain safe temporary access. The Contractor shall take prior approval of the Engineer regarding traffic and water management arrangements during construction.

The Contractor may be allowed to stop traffic temporarily. The period of such closure shall be as agreed by the Engineer at least 14 days in advance, to enable the Engineer to issue the relevant notices.

C. Temporary Stream Diversion

Where hydraulic structures are required to be constructed in the river, drains, natural stream etc., Cofferdam and/or diversion channel as a temporary diversion may be required to exclude the flow of water from the working site and keep the workplace dry. The Contractor shall plan, design, construct, repair and maintain all necessary diversion works including cofferdam, channels, flumes, drains, sumps and any other temporary diversion and protective works.

Diversion structures shall be constructed in such a manner that the water can be smoothly supplied downstream without overtopping and damaging any part of the structures.

The Contractor shall submit design and drawings showing his proposed method for construction of diversion structures to the Engineer for approval before the construction. The diversion structure shall be designed based on the available foundation, flow regime, design requirements, structural stability and material suitability. Approval of the design and drawings by the Engineer shall not in any way relieve the Contractor of his responsibility for the adequacy of the design for strength and stability or for the safety of the people working therein.

Diversion structures shall be maintained throughout the construction of hydraulic structures in order to exclude water from the work site. Leakage, seepage, erosion, settlement, rain cuts, scour and other defects shall be promptly repaired to stop any possible leakage towards the working site.

Following the completion of construction of hydraulic structures in the river, the diversion structures which are no longer required shall be removed and the river flow shall be reinstated.

D. Temporary Road Diversion

Where some portions of the existing road cannot be used by through traffic, due to construction activities, diversions as may be required to deviate traffic from such portions shall be constructed. The contractor

shall design, construct, and maintain all temporary diversions according to standard traffic regulations. Roadways must remain safe, well-lit, and clear of construction debris.

If diversions are provided, they shall include the construction of temporary gates, grid gates, fences, drainage works, and other incidentals as considered necessary depending on the site condition by the Engineer.

The usable width for accommodation of two-way traffic shall not be less than 6m. Where diversions consist of two separate one-way lanes the minimum usable width of each lane shall not be less than 3.5 m.

All necessary temporary drainage works required for proper surface run-off, such as side drains, catch water drains, temporary cross-drainage structures, etc. shall be constructed.

All temporary access routes and traffic diversions shall be maintained in a safe and serviceable conditions. Temporary water-diversion works, drainage channels, pumping systems and protective works shall be inspected regularly and maintained so that the required water levels, flows and working conditions are sustained. All drainage works shall be maintained in good working conditions and kept unblocked.

When temporary traffic diversions, access arrangements or other temporary works following the completion of construction, the diversions which are no longer required shall be removed and the ground reinstated to its original condition.

E. Temporary Diversion Bridges

Temporary diversion works as temporary bridge as may be required by the site condition shall be constructed by the Contractor as required by the contract. Unless otherwise stated in the contract, the contractor shall construct the diversion works as instructed by the engineer. Where the Contractor is required to prepare Design, Drawing and Specifications of the diversion structure, he shall submit his proposal accompanied by sufficient ground and hydraulic information to enable the Engineer to decide on the stability of the structures.

The Contractor shall maintain the temporary diversion bridge in a condition satisfactory to the Engineer so long as required.

On completion of the works, the Contractor shall obtain the approval of the Engineer before removing the temporary diversion bridge. The materials arising from the removal shall become the property of the Contractor or of the Employer as mentioned in the contract. In the case of the materials becoming the property of the Employer, they shall be transported to the Employer's site camp and neatly stacked at no cost to the Employer.

F. Measurement and Payment

i. Unless stated otherwise, no separate measurement and/or payment shall be made for all materials and works required under this Clause. All costs in connection with the work specified here in shall be considered to be included with other related items of the work in the Bill of Quantities.

ii. When the BOQ explicitly includes a separate item for construction of stream diversion structures such as cofferdam and/or diversion channel, payment for the design, construction including supply of materials, equipment, human resources, repair, maintenance, restoration, demolition and removal of the structures shall be based on the lump sum amount quoted by the contractor. 70% of the amount will be paid after complete installation of the river diversion structure, 20% of the amount is for repair, maintenance or reinstatement (if required) of the diversion works and will be paid annually based on the overall progress of the contract and the remaining 10% shall be paid when diversion structures are no more necessary and installments are removed and river flow reinstated. In cases where the diversion structures have to be installed in several stages, the lump sum amount will be split in as many payments as number of stages described in the method statement.

iii. Construction and maintenance of Temporary Diversion Bridge for the required period if quantified in Bill of Quantities (BOQ) shall be paid as per contract unit rates of respective items. The contract price and/or rates shall be the full and the final compensation to the Contractor as per Clause115.

109 PUBLICLY AND PRIVATELY OWNED SERVICES

A. If any privately owned service for water, electricity, drainage, etc., passing through the site is affected by the works the Contractor shall provide a satisfactory alternative service in full working order to the satisfaction of the owner of the services and of the Engineer before terminating the existing service.

B. Drawing and scheduling the affected services like water pipes, sewers, cables, etc. owned by various authorities including Public Undertakings Local Authorities included in the contract documents shall be verified by the Contract or for the accuracy of the information prior to the commencement of any work.

C. Notwithstanding the fact that the information on affected services may not be exhaustive, the final position of these services within the works shall be supposed to have been indicated based on the information furnished by different bodies and to the extent the bodies are familiar with the final position. The Contractor must also allow for any effect of these services and alternatives upon the works and for arranging regular meetings with the various bodies at the commencement of the contract and throughout the period of the works in order to maintain the required co-ordination. During the period of the works, the Contractor shall agree if the public utility bodies vary their decisions in the execution of their proposals in terms of programme and construction, provided that, in the opinion of the Engineer, the Contractor has received reasonable notice thereof before the relevant alternations are put in hand.

D. No clearance or alternations to the utility shall be carried out unless instructed by the Engineer.

E. Any services affected by the works shall be restored immediately by the Contractor who must also take all measures reasonably required by the various bodies to protect their services and property during the progress of the works.

F. The Contractor may be required to carry out the removal or shifting of certain services/utilities on specific instruction from the Engineer for which payment shall be made to him. Such works shall be taken up by the Contractor only after obtaining clearance from the Engineer and ensuring adequate safety measures.

G. Unless stated otherwise, no separate measurements and payment shall be made for the work of temporarily supporting and protecting the publicly and privately owned services and/or for construction and maintenance of new services in lieu of them.

110 EXISTING IRRIGATION SYSTEM AND FLOW TO BE MAINTAINED

The Contractor shall provide all Temporary Works and do all things which may be necessary to maintain those parts of the existing irrigation and drainage system which may be affected by these operations in a condition not less satisfactory than they were prior to the commencement of the Works and shall maintain the normal irrigation supplies therein except when written permission to vary the supplies has been obtained from the Engineer.

When ordered by the Engineer the Contractor shall make connections and carry out such other works as may be necessary to transfer the supply of irrigation water between the existing system of canals and the system constructed under the contract. The Contractor shall submit to the Engineer his detailed proposals for carrying out this work.

The Contractor shall not start the work without the written approval of the Engineer and the cost of all such Temporary Works and all other charges arising from compliance with this Clause shall be deemed to be included in the Contract Rates.

111 MAINTENANCE OF ACCESS ROAD

A. The Contractor shall be responsible for undertaking all routine maintenance of the existing and/or temporarily constructed access road being used by the contractor for transportation of construction materials for execution of the contract from the day the work site is officially handed over to the Contractor until the last date of use of road determined by the Engineer.

B. The routine maintenance of the access road shall include besides other, trimming vegetation, cleaning all culverts, ditches, borrow pits, road side drainage, drainage channels and any other

obstructions including minor landslide (up to 20 m3 at one spot, with unlimited number of spots), cleaning road signs and checking and undertaking the repair of guard rails and other road safety structures, cleaning including removal of obstructions on bridge decks and bridge deck drainage elements and protection of adjoining works. The surface shall be maintained to ensure longitudinal and transverse profile. All the damages to the road carriageway and shoulder shall be repaired with material of equal or higher standard than the original surfacing.

The Contractor shall perform the maintenance works as often as required to keep the carriageway, shoulders, and adjoining structures in proper working order to the satisfaction of the Engineer.

During the period of commencement of works the Contractor shall mobilize labour and equipment to make an immediate start on the maintenance of the existing road. The location and scope of the maintenance work shall be as directed by the Engineer.

Existing ditches shall, where shown on the Drawing, be cleared by removing vegetation growths and deposits. The sides shall be trimmed throughout and the bottoms uniformly graded and the ditches kept clean and trimmed and maintained so long as required. Material removed from the existing ditches shall be disposed off at the places as directed by the Engineer.

Should at any time the Engineer gives any instruction for the upkeep of a section of the road/site and the Contractor does not respond in 48 hours, the Engineer shall be empowered to instruct others to carry out the works. Any costs involved by this action shall be deducted from any money due to the Contractor.

C. Measurement and Payment

Maintenance of access road during construction period as quantified in Bill of Quantities (BOQ) shall be paid as per contract lump sum rate based on overall progress of the work. The contract price and/or lump sum rate shall be the full and the final compensation to the Contractor as per Clause115.

112 ENVIRONMENTAL PROTECTION WORKS

The environment means the surrounding area including human and natural resources that may be affected by the execution and after completion of works.

The Contractor shall take all precautions for safeguarding the environment during the course of the construction of the works. He shall abide by all prevalent laws, rules and regulations governing pollution and environmental protection mitigation measure specified in the EPA/EPR, Latest Publication of **"Environmental Management Guidelines**", and **"Environmental and Social Management Framework"** published by the concerned Government agency.

The Contractor shall prohibit employees from unauthorized use of explosives, poaching wildlife and cutting trees. The Contractor shall be responsible for any such action of his employees.

Environmental protection works, among others, shall also include the following:

A. Borrow/Quarry Sites

The Contractor shall obtain the permission of the Engineer before opening up any borrows pits or quarries. Such borrow pits and quarries may be prohibited or restricted in dimensions and depth by the Engineer where:

(i) They might affect the stability or safety of the works or adjacent property;

(ii) They might interfere with natural or artificial drainage or irrigation;

(iii) They may be environmentally unsuitable.

At least 14 days before he intends to commence opening up any approved borrow pit or quarry, the Contractor shall submit to the Engineer his intended method of working and restoration. These shall include but not be limited to:

(iv) The location, design and method of construction of any access track;

(v) The volume and nature of materials to be removed;

(vi) The sequence and method of excavation of materials;

(vii) Measures for controlling run-off and sediment from the site during operations;

(viii) Proposals for site restoration including approximate finished levels, drainage, erosion and sediment control, and slope stabilization and revegetation, including reinstatement of any access track.

Operations of borrow pit or borrow area shall not be permitted until the method of working for that particular pit or area has been approved by the Engineer in writing. Restoration shall be to the satisfaction of the Engineer.

B. Disposal of Spoil and Construction Waste

Materials in excess of the requirements for permanent works and unsuitable materials shall be disposed off in locations and in the manner as agreed with the Engineer. The locations of disposal sites shall be such as not to promote instability, destruction of properties and public service systems. Exposed areas of such disposal sites shall be suitably dressed and be planted with suitable vegetation.

The Contractor shall plan his works in such a way that there is no spillage of POL (Petroleum Oil Lubricants) products to the surface or sub-surface water.

C. Provision and Maintenance of Toilets

Provision of toilets for labour and employees shall be made to avoid public nuisance as well as pollution of water courses and air. The Contractor shall construct suitable septic tanks and/or soak pits along with room of pit-type latrines. Sufficient water must be provided and maintained in the toilets. Proper methods of sanitation and hygiene should be employed during the whole project duration.

D. Provision of Potable Water

The Contractor shall supply potable water along with commencement of work to Contractor's staff and work person both at camps and construction-sites. This arrangement shall be enforced to avoid proliferation and generation of various waterborne diseases.

The Contractor shall inform the Engineer regarding sources, installation and operation of supply of potable water within a week after the supply is commenced.

E. Provision of First Aid/Medical Facilities

Provision of first aid/medical facilities shall be made along with commencement of work to provide quick medical service to injured/sick work person, and employees. Services shall also include on-the way service and other arrangements required for taking them to the nearest hospital in case of emergency.

The scope of works shall include service of at least one part-time experienced health worker/health assistant with a minimum of once-a-week full-time site visit as work assignment. The Contractor shall also supply and provide adequate medicines and facilities required for standard first aid.

The Contractor shall inform the Engineer regarding the medical facility within a week

after its establishment and operation.

F. Crushing Plants

Crushing plants shall be located away from the population centers, water intakes and should not disturb the sensitive ecosystem. Suitable dust control devices shall be filled to be the crusher to control emission of dust from the plant.

G. Batching Plants

Batching plants shall be located away from the population centers. The Contractor shall take every precaution to reduce levels of noise, vibration, dust and emission from his plants.

No waste concrete material shall be discharged into drains. Nearby trees, vegetation and property shall be

protected during carriage of mixed concrete by transit mixers.

H. Hazardous Materials

The Contractor shall not store hazardous materials near water surfaces. The Contractor shall provide protective clothing or appliances when it is necessary to use some hazardous substances.

High concentration of airborne dust resulting in deposition and damage to crops and water resources shall be avoided. The Contractor shall take every precaution to control excessive noise resulting in disruption to wildlife and human population.

Only controlled explosives methods shall be applied and used in construction works.

I. Reinstatement of Environment

The Contractor shall arrange and execute works as well as related activities in such a way that environmental conditions are reinstated. He may be required to carry out filing, removal and disposal works along with plantation of grass and trees as directed by the Engineer at his own costs at identified locations to reinstate environment.

Written instruction/approval shall be given by/sought from the Engineer regarding reinstatement of environment both during and after completion of works and up to the end of Defects Liability Period.

J. Measurement and Payment

Unless stated otherwise, no separate measurement and payment shall be made for the works described in this Clause.

113 LABORATORY AND CONTRACTOR'S TEMPORARY FACILITIES

A. Field Laboratory

(1) Location

The Contractor shall arrange fully furnished and adequately equipped field Laboratory on the site as described in the contract. It shall be located at suitable location approved by the Engineer and provided with amenities like water supply, electric supply. It shall be established specifically for the specified contract.

(2) Setup

Field laboratory to be established under the contract shall be set up not later than sixty (60) days after the Engineer issue a letter of commencement of the works and shall be in fully operating condition.

Construction works related with laboratory tests shall not be permitted until the laboratories have been accepted by the Engineer.

(3) Laboratory Equipment

All equipment necessary for the testing of materials and workmanship shall be delivered to the site in accordance with the schedule of requirements described therein. The Contractor shall establish and maintain a field laboratory at the site, equipped with the required items of laboratory equipment, subject to the approval of the Engineer. For guidance, a list of laboratory equipment is provided in Table 1.1; however, this list shall be considered indicative only, and the Engineer may require additional or alternative equipment as necessary to ensure compliance with the specifications and standards of the Contract. The Contractor shall remain fully responsible for the timely delivery, installation, calibration, and maintenance of the laboratory equipment throughout the Contract Period, and any delay or non-compliance shall be treated in accordance with the Conditions of Contract.

Table 1.1 List of Laboratory Equipment

SN	DESCRIPTION OF EQUIPMENT	QTY
A	GENERAL	
1	Weigh balance	
	i) 5 – 20 kg Capacity electronic type accuracy 1 gm	1 No
	ii) 500 gm capacity electronic type accuracy 0.01 gm	1 No
	iii) 5 Kg capacity electronic type accuracy 0.05 gm	1 No
	iv) Platform Balance scale- 300 Kg capacity	1 No
	v) Chemical Balance 100 gm capacity Accuracy 0.001 gm	1 No
2	Oven – Electrically operated, thermostatically controlled, (including thermometer) stainless steel interior range up to 200° C sensitivity 1 °C	1 No
3	i) Set of IS sieves as per IS 462 with lid and pan: 450 mm. diameter; 63mm, 53mm, 37.5mm, 26,5mm, 13.2mrn, 9.5 mm 6.7mm and 4.75mm size	1 set
	ii) Set of IS sieves as per IS 462 with lid and pan: 200 mm diameter (Brass frame and steel / or brass wire cloth mesh) : 2.36mrn, 2.0mm, 1.18mm, 600micron, 425micron, 300micron, 150micron, and 75micron	2 set
4	Sieve shaker capable of asking 200 mm and 450 mm dia. sieves electrically operated with time switch	1 No
5	200 ton compression testing machine for concrete cube test	1 No
6	Stopwatch 1/5 sec , accuracy	1 No
7	Glassware comprising beakers, pipettes, dishes, measuring cylinders (100 to 1000 cc capacity) glass rods and funnels, glass thermometers range 00 to 1000C and metallic thermometers range up to 3000C	2 No each
8	Hot plate 200 mm dia. (1500 watt)	1 No
B	FOR SOILS	
1	Liquid limit device with ASTM grooving tools as per IS 2720	1 No
2	Sampling pipettes fitted with pressure and suction inlets, 10 ml capacity	1 set
3	Compaction apparatus (Proctor) as per IS 2720 (part 7) complete with collar, base plate and hammer with all other accessories	1 Set
4	Modified AASHTO Compaction apparatus as per IS 2720 (part 8) or heavy compaction, complete with collar, base plate and hammer with all other accessories	1 set
5	Sand pouring cylinder with conical funnel and tap and complete as per IS 2720 part 28 including modern equipment	2 Sets
6	Apparatus for compaction test by sand replacement method	2 Sets
7	Sampling tins with lids 100 mm dia. X 75 mm ht ½ Kg capacity and miscellaneous items like moisture tins 50 grams etc.	4 No
9	Standard Penetration test equipment	1 No
10	Speedy moisture meter complete with chemicals	1 No
11	Unconfined Compression Test Apparatus	1 Set
C	FOR CEMENT, CEMENT CONCRETE AND MATERIALS	
1	Water still	1 No
2	Vicat needle apparatus for setting time with plungers as per IS 269	1 set
3	Mould : 150 mm cube, 100 mm cube, 70.7 mm cube and 150 mm dia. 30 mm ht cylinder	As required
4	Concrete permeability apparatus	1 set
5	High frequency mortar cube vibrator for cement testing	1 No
6	Concrete mixture power driven 1 cu. Ft capacity	1 No
7	Variable frequency and amplitude vibrating table size 1m X 1 m	1 No
8	Flakiness index test apparatus	1 set
9	Aggregate impact test apparatus as per IS 2386 part 4	1 set
10	Los Angeles abrasion test apparatus as per IS 2386 part 4	1 set

11	Slump test apparatus	1 set
12	Specific gravity test apparatus for fine and coarse aggregates as per IS : 2386 part 3	1 set
13	Compression and flexure strength testing machine 200 T capacity with additional dial for flexural testing	1 set
14	Core cutting machine with 10 cm diamond cutting edge	1 set
15	Needle vibrator	2 Nos
16	Soundness testing apparatus for cement (Lee chattlier)	1 set
D	FOR CONTROL OF PROFILE AND SURFACE EVENNESS	
1	Total station with accessories	1 set
2	Automatic level with micrometer attachment	1 set
3	Distomat or equivalent	1 set
4	Theodolite with electronically operated with computerized output attachment	1 set
5	Staff (Precision)	2 set
6	3 meter straight edge and measuring wedge	1 set
7	Steel tape; 5m, 10 m, 20 m, 50 m long	2 no each

Note: *The Items and their numbers listed above table are indicative only and shall be decided by the Engineer as per requirements of the Project and modified accordingly*

(4) Ownership

Unless otherwise stated in the contract the ownership of all laboratories and equipment shall revert to the Contractor.

(5) Maintenance

The Contractor shall responsible to keep the Laboratories in a well maintained, clean and working condition until issuance of taking over certificate for the completed works.

The Contractor shall provide all tools, consumable items for testing and all the assistance as may be required by the Engineer and his staff for measuring and checking the works.

(6) Measurement

The field laboratory established and approved by the Engineer shall be measured in unit specified in BOQ of the contract.

(7) Payment

The payment of laboratory building including services, essential supplies like water, electricity, sanitary services and their maintenance and cost of all equipment, tools, materials, labor and incidentals to perform tests and other operations of quality control according to the Specification requirements shall be made in three installments. Sixty percent (60%) of the quoted amount shall be paid only after the specific area has been completed and ready for use. Thirty-Five percent (35%) of quoted amount shall be paid on annual basis based on the progress of overall works and the remaining five percent (5%) shall be paid after the removal of fixed facilities and restoration of site.

B. Alternate Lab Tests

For performing the required laboratory tests as per the standard specifications in laboratories other than the established field laboratory, the Contractor shall carry out such tests in a laboratory approved by the Engineer, in accordance with the Engineer's instructions. The cost incurred for such tests shall be deemed to be included within the relevant Bill of Quantities (BoQ) items and borne by the Contractor. However, if the Engineer or Employer requires additional third-party tests beyond those specified in the Contract, the Contractor shall perform such tests in a laboratory approved by the Engineer, and the reasonable and documented costs of such additional tests shall be reimbursed to the Contractor from the Provisional Sum established in the BoQ of the Contract.

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Department of Water Resources and Irrigation
Jawalakhel, Lalitpur

C. Contractor's Temporary Facilities

(1) Provision and Maintenance of Camps, Offices, Stores, Equipment Yards and Workshops

The Contractor shall be responsible for construction (or providing), maintenance, operation and subsequent removal of Contractor's temporary facilities such as camps for work person and employees, Contractor's site offices, stores, equipment yards and workshops. These camps must be adequate, rain-proof, spacious, airy and hygienic with proper lightning and materials storage facilities. The area shall be kept neat and clean.

Space allocated for storage of materials such as cement, gabion wire, reinforcing wire etc. shall in general be damp-free, rain-proof and away from petroleum products storage.

Written information must be given to and approval be taken from the Engineer regarding proper establishment and maintenance of such camps.

Failure in compliance with Engineer's instruction in respect of overall standard will Lead to reduction or withholding of payment.

(2) Payment

Unless stated otherwise, no separate measurement and payment shall be made for the works described in this Sub-clause. However, if the BoQ specifically provisioned payment item for Provision and Maintenance of Camps, Offices, Stores, Equipment Yards and Workshops, then such amount shall be paid in the fixed percentage of these works. Seventy per cent (70%) of total lump sum price of these temporary works shall be paid to the Contractor upon completion of construction/establishment of these temporary facilities, 15 % of total lump sum price shall be paid on annual basis based on the certified financial progress of the total construction works and the remaining 15 % shall be paid after site restoration.

In the event that the Contractor establishes temporary facilities on land owned by the Project, such land shall be reinstated to its original or agreed condition upon completion of the works, to the satisfaction of the Engineer. If such facilities are constructed on land rented or leased from a private individual or external agency, the Contractor shall submit a formal No Objection Letter or equivalent clearance document from the landowner or agency concerned, confirming that the temporary use has been duly vacated and that no further obligations remain. This documentation shall be submitted prior to the release of the final payment associated with the removal of temporary facilities.

114 INSURANCE AND COMMISSION FOR PERFORMANCE BOND

A. Insurance Of Works, Damage To Property, Loss To Third Party And Accident To Workmen

(1) General

The Contractor shall provide, in the joint names of the Employer and the Contractor, insurance cover as per the provision included in the Conditions of Contract from the Start Date to the end of the Defects Liability Period, in the amounts and deductibles stated in the Contract Data for the following events which may arise out of the Contractor's performance of the contract:

(a) Loss of or damage to the Works, Plant and Materials;

(b) Loss of or damage to Equipment;

(c) Contractor's Workmen and Employees

(d) Third Party Liability Insurance;

(2) Payment

The Contractor shall produce the insurance policy from any insuring company operative and recognized within Nepal. The Contractor shall, immediately after securing the insurance policy (ies) shall produce to the Engineer the original bills paid against the premiums. Payments made to the insuring company and stamp charges/duties incurred if any, by the Contractor in compliance of the above work shall be paid from

the Provisional Sum established in the BoQ of the Contract after submission of the insurance document to the satisfaction of the Engineer.

The payment for insurance services shall be made on an installation basis. The seventy (70) percent of the amount shall be paid to the contractor in the first Interim Payment Certificate and remaining thirty (30) percent of the amount shall be paid on an annual basis depending on the progress of the overall works. Unpaid balance if any of the insurance services shall be released to the Contractor in the Final Payment Certificate.

If the Contract Period is extended due to the issuance of Variation Order by the Engineer/Employer, and such Variation necessitates extension of the Insurance Policy, the Employer shall reimburse the Contractor for the additional costs incurred, subject to submission of verifiable supporting documents and approval by the Engineer.

If the Contract Period is extended for delays attributable to the Engineer or Employer, the Contractor shall bear the cost of extending the Insurance Policy up to a cumulative period of six (6) months for projects with a Contract Price less than NPR 5,000 million, and up to twelve (12) months for projects with a Contract Price exceeding NPR 5,000 million, beyond the original Contract Period. Such costs shall be deemed included within the overall Bill of Quantities (BoQ) items and the Contract Price. If the cumulative extension period due to reasons not attributable to the Contractor exceeds six (6) months or twelve (12) months, as the case may be, the Employer shall reimburse the Contractor for the reasonable and documented costs of extending the Insurance Policy for the period exceeding such threshold, subject to submission of verifiable supporting documents and approval by the Engineer.

Any additional costs incurred for extension of the Insurance Policy due to delays or extensions arising from the Contractor's default shall be borne solely by the Contractor. No separate or additional payment shall be made in such cases, even if the Employer grants an extension of time to complete the Works.

B. Commission For Performance Bond

(1) General

The Contractor shall submit the required Performance Bond(s) at the time of Contract Agreement in accordance with the Conditions of Contract. Upon submission and approval by the Engineer, the cost incurred by the Contractor in preparing such bond(s) shall be paid under the lump sum price quoted in the Bill of Quantities or under the Provisional Sum expressly allocated for this purpose.

(2) Payment

Initial Payment: Seventy percent (70%) of the quoted lump sum shall be disbursed under the first Interim Payment Certificate following approval of the Performance Bond(s).

Subsequent Payment: Thirty percent (30%) shall be paid annually, proportionate to the certified financial progress of the Works, as determined by the Engineer. Unpaid balance if any of the Performance Bond item shall be released to the Contractor in the Final Payment Certificate.

If the Contract Period is extended due to the issuance of **Variation Order by the Engineer/Employer**, and such Variation necessitates extension of the Performance Bond(s), the Employer shall reimburse the Contractor for the additional costs incurred, subject to submission of verifiable supporting documents and approval by the Engineer.

If the Contract Period is extended for delays attributable to the Engineer or Employer, the Contractor shall bear the cost of extending the Performance Bond(s) up to a cumulative period of six (6) months for projects with a Contract Price less than NPR 5,000 million, and up to twelve (12) months for projects with a Contract Price exceeding NPR 5,000 million, beyond the original Contract Period. Such costs shall be deemed included within the overall Bill of Quantities (BoQ) items and the Contract Price. If the cumulative extension period due to reasons not attributable to the Contractor exceeds six (6) months or twelve (12) months, as the case may be, the Employer shall reimburse the Contractor for the reasonable and documented costs of extending the Performance Bond(s) for the period exceeding such threshold, subject to submission of verifiable supporting documents and approval by the Engineer.

Any additional costs incurred for extension of the Performance Bond(s) due to delays or extensions arising from the Contractor's default shall be borne solely by the Contractor. No separate or additional payment shall be made in such cases, even if the Employer grants an extension of time to complete the Works.

115 NOTES ABOUT MEASUREMENT AND PAYMENT

A. Measurement

Unless otherwise specified, all measurements shall be made in metric system. Different items of work shall be measured in accordance with the procedures set forth in the relevant Sections read in conjunction with the General conditions of Contract. The same shall not, however, apply in the case of lump sum contracts.

All measurements and computations, unless otherwise indicated, shall be carried nearest to the following limits:

(i) Length and Width - 10 mm

(ii) Height, Depth or Thickness of:

a. Earthwork in excavation - 5 mm

b. Embankment - 5 mm

(iii) Structural members- 2.5 mm

(iv) Areas- 0.01 m^2

(v) Volume- 0.01 m^3

In recording dimensions of work, these limit of tolerances for accuracy of length, width and height or depth or thickness shall be followed.

The tolerances specified in these Specifications are for evaluation of accuracies only based on which the work shall be accepted or rejected. However, the measurement of the work performed within the limits of tolerances shall be the measurement of actual work done in place, if their dimensions are less than what have been specified or instructed by the Engineer. If the actual work done in place is more than what has been specified or instructed by the Engineer, but within the limit of tolerance, the measurement shall be the measurement of the work what has been specified or instructed by the Engineer.

B. Payment

Unless otherwise specified in the Contract, the unit rates and/or prices for items as set out in the Bill of Quantities are the full and the final compensation to the Contractor for:

(i) General works such as setting out, clearance of site before setting out and clearance of works after completion;

(ii) A detailed programme using modern project management software for the construction and completion of the works giving, in addition to construction activities, detailed networks activities for the submission and approval of materials, procurement of critical materials and equipment, fabrication of special products/equipment and their installation and testing, for all activities of the Engineer/Employer that are likely to affect the progress of works, etc., including updating of all such activities on the basis of the decisions taken at the periodic site review meting or as directed by the Engineer;

(iii) Sampling and Testing of various materials such as reinforcement, cement, concrete, GI wire, bearing etc. proposed to be used on the Works as required under these Specifications and furnishing test reports/certificates;

(iv) Design of mixes as per the relevant Sections of the Specifications giving proportions of ingredients, sources of aggregates and binder along with accompanying trial mixes as per the relevant Sections of these Specifications to be submitted to the Engineer for his approval before use on the Works;

(v) Cost of laying trial stretches;

(vi) Preparation of Detailed drawings as per site condition;

(vii) Detailed design calculations and drawings for all Temporary Works (such as formwork, staging, centering, specialized constructional handling and launching equipment and the like);

(viii) Detailed drawings for templates, support and end anchorage, details for bar bending and cutting schedules for reinforcement, material lists for fabrication of structural steel, etc.;

(ix) Mill test reports for cement, GI wires, all mild and high tensile steel and cast steel as per the relevant provisions of the Specifications;

(x) Supply of all materials necessary to complete the item of work as per relevant specifications;

(xi) Use of materials, labours, tools, equipment, machines and other resources as per need;

(xii) All handling, packing charges and transportation;

(xiii) Site commissioning;

(xiv) Cost of all operations like storing, erection, moving into final position, etc. necessary to complete and protect the work till handing over to the Employer;

(xv) Inspection Reports in respect of formwork, staging, reinforcement and other items of work as per the relevant Specifications;

(xvi) Any other data which may be required as per these Specifications or the Conditions of Contract or any other annexures/schedules forming part of the Contract;

(xvii) All temporary works, form work and falsework;

(xviii) Cost of in-built provisions for Quality Assurance;

(xix) Maintenance and making good;

(xx) All duties and obligations as set out in the contract;

(xxi) All incidental costs to complete the work, and other items necessary for complying with the provision of the Contract not covered under above stated;

Where the Bill of Quantities does not include the items mentioned in Section 100, no separate payment shall be made for such works. The costs in connection with the execution of the works specified herein shall be considered to be included in the related items of other works specified in the Bill of Quantities or shall be considered to be incidental to the works specified. Items specified in this Section and included in the Bill of Quantities shall be paid at the contract unit rates as agreed and shown in the Bill of Quantities.

116 UNITS OF MEASUREMENT, ABBREVIATION AND TERMINOLOGY

A. Units of Measurement

The Symbols for units of measurement used in these Specifications are as they are given below.

Abbreviation	Full Form	Abbreviation	Full Form
µ	: Micron = $m \times 10^{-6}$	°C	: Degrees Celsius
mm	: Millimeter	Kg	: Kilogram
m	: Meter	Gm	: Gram = $kg \times 10^{-3}$
Km	: Kilometer	mg	: Milligram = $kg \times 10^{-6}$
sq. mm. or mm^2	: Square Millimeter	mg/l	: Milligram per liter
Sq. m. or m^2	: Square Meter	T	: Ton = $kg \times 10^3$
Sq. km. or km^2	: Square Kilometer	Kg/m^3	: Kilogram per cubic meter
Ha/ha	: Hectare	t/m^3	: Ton per cubic meter
Cu.m. or m^3	: Cubic Meter	N	: Newton
lit or l	: Liter	N/m^2	: Newton per square meter

Symbols of other units, if not covered above, shall be as per SI system set out in ISO 31/1.

B. Abbreviations

The following abbreviations are used in these Specifications.

Abbreviation	Full Form	Abbreviation	Full Form
ACV	: Aggregate Crushing Value	PI	: Plasticity Index
AIV	: Aggregate Impact Value	PL	: Plastic Limit
ALD	: Average Least Dimension	PM	: Plasticity Modulus (PI*%passing 0.425mm sieve)
BA	: Bitumen Affinity	POL	: Petrol, Oil & Lubricant
BOQ	: Bill of Quantities	ROW	: Right of Way
CBR	: California Bearing Ratio	SE	: Sand Equivalent
CR	: Crushing Ratio	Sec	: Second
Dia	: Diameter	SG	: Specific Gravity
DWRI	: Department of Water Resources and Irrigation	IS	: International Standard Units of Measurements
FI	: Flakiness Index	SSS	: Sodium Sulphate Soundness test, loss on 5 cycles
Hr/hr	: Hour	STV	: Standard Tar Viscosity
LAA	: Los Angeles Abrasion Value	TS	: Tensile Strength
LS	: Linear Shrinkage	UC	: Uniformity Coefficient
MC	: Moisture Content	UCS	: Unconfined Compressive Strength
MDD	: Maximum Dry Density	VIM	: Voids in Mix
Min/min	: Minute	W/c	: Water cement ratio
No	: Number (Units) as in 6 no	wt	: Weight
OMC	: Optimum Moisture Content	%	: Percent

C. Terminology

The term “the Specifications” shall be construed as the Standard Specification and the Special Specification altogether.

The Sections, Clauses and/or Sub-Clauses mentioned in these Specifications deem to apply to those of these Specifications only, if otherwise not specified.

117 PROGRAM

The Contractor shall provide all information needed for fulfilment of the program and required in accordance with the Conditions of Contract including the sequence in which he intends to work including implementation of quality assurance plan. If the Contractor requests a change in the sequence and such change is approved by the Engineer, the Contractor shall have no claim as per the Conditions of Contract for delay arising from such revisions to the program.

The program for the construction and completion of the works shall be established using CPM/PERT techniques or equivalent. The program shall be detailed enough to give, in addition to construction activities, detailed network activities for the submission and approval of materials, procurement of critical materials and equipment, fabrication of special products/equipment’s if any their installation and testing, and for all activities of the Engineer that are likely to affect the progress of work. The Contractor shall update all activities in accordance with the Conditions of Contract on the basis of the decision taken at the periodic site review meetings or as directed by the Engineer.

The program shall also include the Contractor’s general requirements for any road closures to be agreed in principle with the Engineer. Such agreement shall not relieve the Contractor of his responsibility to obtain specific approval for each closure or series of closures.

Nightworks shall generally not be permitted. However, for mass concentrated works night works may be permitted by the Engineer. Under Such circumstances, any such proposal for night working shall also be stated in the program.

118 SUPPLY OF PROJECT RECORD

A. Scope

This Clause covers the supply of digital records of project events in digital format (DVD/ Flash Drive) including colour photographs, both in digital format as well as mounted on albums to serve as a permanent record of the work needed for authentic documentation, as approved by the Engineer.

B. Description

The Contractor shall provide following project records in digital format (DVD/ Flash Drive) including colour photographs as directed by the Engineer;

(i) Record of work in each work front: It shall cover the status of each work front before start of work, during various stages of construction and after completion duly including the arrangements made (day and night) during construction. (This shall be need based or as directed by the Engineer)

(ii) Record of quarry sites, plant sites, camp sites including labour camps, haul roads, access road etc. with progress report

(iii) Records of all accidents on various sites of the project

The record shall be taken by a professional with a digital camera capable of taking still as well as video images having facilities to record the date and background commentary. The Contractor shall keep separate discs/drives, one with the Engineer and the other with the Employer and update the data in these disc/drives as per Instruction of Engineer or on monthly basics. Separately, a video (in digital format)of maximum one hour duration covering interesting and novel features of the work duly editing the above master disc/drive shall also be maintained, one copy each kept with the Engineer and the Employer and updated as per direction of Engineer or on monthly basis. All recording shall be done in the presence of the Engineer's Representative who will certify in writing the recording.

C. Measurement

This item shall be measured in number of sets. Each set consist of two copies of all digital records as above and colour record photographs both in digital format as well as mounted in the albums.

D. Payment

The contract unit rate shall include all expenses for supply of project record including video recordings updated as per direction of Engineer or on monthly basis throughout the construction period shall be measured as single set.

SECTION 200: SITE PREPARATION

201 CLEARING AND GRUBBING 2-1

(1) Scope 2-1

(2) Description of Work 2-1

(3) Execution of Work 2-1

(4) Measurement 2-3

(5) Payment 2-3

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(1) Scope 2-3

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201 CLEARING AND GRUBBING

(1) Scope

The Section covers the clearing and grubbing necessary for the construction of the works covered by the contract. Conservation of suitable topsoil, existing vegetation and designated flora is also covered under this Section.

(2) Description of Work

(a) Clearing

Clearing shall consist of the cutting, removing and disposal of all trees, bushes, shrubs, grass, weeds, other vegetation, anthills, rubbish, fences, top organic soil not exceeding 150 mm in thickness and all other objectionable material, resulting from the clearing and grubbing. It shall also include the removal and disposal of structures that obtrude, encroach upon or otherwise obstruct the work.

The moving of a certain amount of soil or gravel material may be inherent to or unavoidable during the process of clearing and no extra payment shall be made for this. Clearing shall include the removal of all rocks and boulders of up to 0.15 m^3 in size exposed or lying on the surface.

(b) Grubbing

In areas of canal excavation, canal embankment and other permanent works, all trees up to 120 mm girth, stumps and roots shall be removed to a depth of not less than 500 mm below the original ground level, or to such greater depth as may be necessary to completely remove the roots and organic material and properly prepare the formation, as directed by the Engineer.

Except in borrow areas the cavities resulting from the grubbing shall be backfilled with approved material and compacted to a density not less than the density of the surrounding ground.

(c) Conservation of Topsoil

Where suitable topsoil exists within the limits of the area to be cleared and grubbed, the Contractor shall, if ordered by the Engineer, remove the topsoil together with any grass and other suitable vegetation. If not used immediately, the topsoil shall be transported and deposited in stockpiles for later use.

(d) Conservation of Flora

Where provided for in the contract, certain designated flora encountered in the canal reserve and borrow areas shall be carefully protected by the Contractor. In his tendered rate for Site Clearance, he shall include for the careful removal and planting of the flora in a protected and fenced-off area and, on completion of the canal, for there planting of the flora in suitable positions in the canal reserve in accordance with the Engineer's instructions.

(3) Execution of Work

(a) Areas to be Cleared and Grubbed

Stumps, embedded logs, roots and all other vegetation growth and accumulated rubbish of whatsoever nature and all other objectionable material shall be completely removed to adept has specified in Sub-clause 201 (2) (a) and (b).

Normally, the areas falling within the limits of canal excavation and embankments, hydraulic structures, river-training and flood-protection works, as well as designated borrow areas, shall be cleared and/or grubbed. The full extent of the areas required for construction shall be cleared and/or grubbed, except for such trees and other vegetation designated by the Engineer to be left standing and uninjured.

The Contractor shall mark the boundaries of the area for clearing and grubbing and seek the approval of the Engineer before commencement of the work. The Engineer shall designate in detail the exact areas to be cleared and grubbed and the time at which it shall be done.

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(b) Cutting of Trees

The Contractor shall take the necessary precautions not to damage to structures and other private or public property. If necessary, trees shall be cut in sections from the top downwards. The branches of trees to be left standing shall be trimmed so as not to interfere with the construction, operation or maintenance of the works.

Such individual trees as the Engineer may designate and mark in white paint shall be left standing and uninjured. In order to minimize damage to trees that are to be left standing, trees shall be felled towards the center of the areas being cleared, if so required by the Engineer.

Permission for cutting trees must be obtained from the competent authority who may require that trees be numbered, measured and marked in the presence of officials from that authority. Cutting of such trees shall then be carried out by the Contractor and the timber stored at designated locations.

Felling and cutting of trees on the site and pilling them off the site shall conform to the requirements of the competent authority.

All tree trunks and branches in excess of 150 mm in diameter shall be cleaned off, secondary branches cut into suitable length and stacked at sites indicated by the Engineer. Such timber shall not be used by the Contractor for any purpose and shall remain the property of the Employer.

All timber except such timber as can be used and all brush, stumps, roots, rotten wood and other refuse from the clearing and grubbing operations shall be completely removed from within the occupied space of Canal.

(c) Dealing with Anthills

Where anthills are encountered within the limits of the canal way, they shall be excavated to a depth of not less than 750 mm below the original ground level and the material carted to spoil. Cavities resulting from the clearance of anthill material shall be backfilled as required with approved material and compacted to a density not less than that of the surrounding ground.

Where directed by the Engineer, the area covered by anthills shall be treated, after excavation and before backfilling of cavities, with an approved ant control chemical. Payment for such treatment shall be made in the manner specified in the contract.

(d) Disposal of Material

Material obtained from clearing and grubbing shall be disposed off in borrow pits or other suitable places and be covered up with soil or gravel as directed by the Engineer. The burning of combustible material shall not, normally, be permitted and may only be done with the prior written approval of the Engineer.

Where fences have to be taken down, fencing wire shall be neatly wound into reels and all such wire, together with all fence posts and other serviceable material from structures, etc., shall be stacked at sites indicated by the Engineer.

(e) Reclearing of Vegetation

Where areas have been cleared and/or grubbed in accordance with the Specifications, but vegetation subsequently regrows during the construction period, the Engineer may, where considered necessary, order the Contractor to reclear such areas.

Before construction of canal embankments, river embankments, foundations, structural works or other permanent works, the Contractor shall remove any vegetation that has subsequently grown on surfaces previously cleared and grubbed.

Reclearing shall include the removal and disposal of grass, shrubs, roots and other vegetation in the same manner as the original clearing operation. No separate payment shall be made for reclearing of areas previously cleared and grubbed.

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(4) Measurement

Clearing and grubbing executed as per this Specification shall be measured in square meter.

Cutting trees including removal of stumps and their roots of girth from 120 mm and backfilling to required compaction shall be measured in number according to the sizes given below:

(a) 120 mm to 300 mm

(b) Above 300 mm to 600 mm

(c) Above 600 mm to 900 mm

(d) Above 900 mm to 1200 mm

(e) Above 1200 mm to 1800 mm

(f) Above 1800 mm to 2400 mm

(g) Above 2400 mm to 3000 mm

(h) Above 3000 mm

For this purpose, girth shall be measured at a height 1 meter above the ground. Cutting of trees up to 120 mm girth including removal of stumps and roots and backfilling of holes with compaction shall not be measured separately.

(5) Payment

Clearing and grubbing and cutting trees shall be paid at their respective contract unit rates which shall be the full and the final compensation to the Contractor as per Clause 115. The contract unit rate for cutting of trees of girth above 120 mm shall also include handling, salvaging, piling and disposing off the cleared materials with all leads and lifts.

202 DISMANTLING CANALS, CULVERTS, AQUEDUCTS, SYPHONS, AND OTHER STRUCTURES

(1) Scope

This work shall consist of removing as here in after set forth existing canals, culverts, bridges, aqueducts, syphons, headworks, retaining walls, Hume pipes, fencing, poles and other structure comprising of masonry, cement concrete, woodwork, steel work, buildings etc., which are in place but interfere with the new construction or are not suitable to remain in place, and salvaging and disposing off the resulting materials and back filling the resulting trenches and pits as required.

(2) General

(a) Only those structures designated by the Engineer, or shown on the Drawings, shall be demolished or removed.

(b) Dismantling and removal operations shall be carried out in such a way that the adjacent structures are left intact and in place. All operations necessary for the removal of any existing structure which might endanger new construction shall be completed prior to start of new work.

(c) Existing canals, canal structures, and other structures which are designated for removal shall be removed up to the limits and extent specified on the Drawing or as indicated by the Engineer.

(d) Materials that are to be salvaged shall be carefully removed and stockpiled near the site at a location designated by the Engineer. The cost of Materials which are to be salvaged or used in the reconstruction work, if found damaged or destroyed as a result of the Contractor's operations, shall be borne by the Contractor. Materials that are not to be salvaged and stockpiled, shall be removed and disposed away from the site by the contract or at his own expenses. Existing reinforcement that is to be incorporated in new work shall be protected from damage and shall be thoroughly cleaned of all adhering material before being embedded in new concrete.

(e) When pipe culverts, wooden culverts, gabion walls or other structures with a salvaged value are removed, care shall be exercised in their safe removal. The material involved shall be kept intact without damage. The Contractor shall be responsible for the satisfactory removal of such structures in a usable condition.

(f) Salvaged reinforced concrete pipes, corrugated steel pipes, wooden boxes or other structures shall be stored at places as directed by the Engineer or shown on the Drawing. Structures or portions there of which are specified in the contract for re-erection shall be stored in separate piles.

(g) Timber or lumber from old structures which is designated by the Engineer as materials to be salvaged shall have all nails and bolts removed therefrom and shall be stored in neat piles in locations suitable for loading.

(h) All operations necessary for the removal of any existing structure which might endanger new construction shall be completed prior to the start of new work.

(i) All salvaged materials shall be the property of the Employer.

(j) All materials obtained from dismantling operations which, in the opinion of the Engineer, cannot be used or auctioned shall be disposed off.

(3) Dismantling Culverts, Aqueducts, and Syphons

The structures shall be dismantled carefully, and the materials shall be so removed as not to cause any damage to the serviceable materials to be salvaged. The part of the structure to be retained and other structures nearby shall be safeguarded against any damage.

Where existing culverts/bridges, aqueducts, syphons, regulators, headworks, barrages, weir or other hydraulic structure is to be otherwise incorporated in the new works, only such parts of the existing structure shall be removed as are necessary and directed by the Engineer to provide a proper connection to the new work. The connection edges shall be cut, chipped and trimmed to the required lines and grades without weakening or damaging any part of the structure to be retained.

Steel structures shall, unless otherwise provided, be carefully dismantled in such a manner as to avoid damage to members thereof. The structure shall be removed in a condition suitable for re-erection unless otherwise shown on the Drawing. All members shall be match-marked by the Contractor with white lead paint before dismantling; end pins, nuts, loose plates, etc., shall be similarly marked to indicate their proper location; all pins, pinholes and machined surfaces shall be painted with a mixture of white lead and tallow and all loose parts shall be securely wired to adjacent members or packed in boxes.

(4) Dismantling Other Structures

In removing existing canal linings, masonry, retaining walls, pitching, riprap, gabions, outlets, protection works and other structures where portions of the existing construction are to be left in the finished work, the same shall be removed to an existing joint or cut and chipped to a true line with face perpendicular to the surface of existing structure. All other structures designated for removal shall be broken to pieces whose volume shall not exceed 0.02 cubic meters and stockpiled at designated locations if the materials are to be used later or otherwise arranged for disposal.

(5) Back-filling

Holes and depressions caused by dismantling operations shall be backfilled as required with excavated or other approved materials and compacted to required density as directed by the Engineer.

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(6) Measurement

Prior to commencement of dismantling, the work of dismantling structures shall be measured in the units given below:

SN	Type of Work	Unit
(i)	Dismantling brick/stone masonry/Concrete (plain and reinforced)	cu.m.
(ii)	Dismantling gabion	cu.m.
(iii)	Dismantling steel structures	ton
(iv)	Dismantling timber structures	cu.m.
(v)	Dismantling pipes, guard rails, Kerb sand gutters	lin. m.
(vi)	Utility services (Telephone poles, Electric polrd)	no.
(vii)	Pavement	cu.m.
(viii)	Dismantling pipe culverts	no.
(ix)	Dismantling pitching and ripraps	sq. m.
(x)	Removing hume pipes, wire fencing	m.

Associated works like disposal, stockpiling, marking and numbering, etc., shall not be measured separately.

(7) Payment

The various dismantling works shall be paid at their respective contract unit rates which shall be full and the final compensation to the Contractor as per Clause 115 and for the cost of all operations involved for completion of this item.

SECTION 300: EARTHWORKS

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301 SCOPE

This Section covers the works related to the canal excavation, filling for canal banks and embankments, excavation for foundation, backfilling, excavation for drains, channels etc.

302 DEFINITIONS AND GENERAL REQUIREMENTS

(1) Earthwork includes two types of operations i.e. (i) earth excavation and disposal of the excavated materials (ii) earth excavation and use of excavated materials. The use of excavated material may be in the form of filling canal banks, embankment, backfilling, and filling other areas as required.

Earth excavation and disposal implies excavation of all types of materials including part of the structures below ground level within and outside of the limit of the right of way of canal except for otherwise specified, shaping the exposed surface of excavation as specified or directed by the Engineer, removal, hauling and disposal of the excavated material at the locations and in the manner as specified or directed by the Engineer.

Excavation and filling imply excavation of materials and shaping the exposed surface of excavated as stated, removal hauling and use of the excavated material at the location and in the manner as specified or directed by the Engineer.

Excavation and disposal shall include:

(i) Excavation and disposal of any type of material included on the Drawing.

(ii) The excavation and disposal of existing surfacing.

(iii) Excavation and disposal of slides, breakages and caving-ins.

(iv) Excavation and disposal for canals, stream channel, trenches and drains etc.

(v) Excavation required in cuts or under canal beds/embankments below the lowest normal limit of excavation as indicated on the Drawing or below ground line.

(vi) Excavation and disposal of unsuitable materials.

(vii) Removal or partial removal of existing embankments and disposal of the materials as shown on the Drawing or as directed by the Engineer.

(viii) Excavation for foundation and disposal of materials.

Excavation and filling shall include:

(i) Filling for canal banks and embankment

(ii) Filling for guide bunds, coffer dams, etc.

(iii) Backfilling in trenches, foundation pits etc.

(iv) Any type of other filling or backfilling whereby the ground level is raised or a hole is filled up.

(2) The following definitions of earthworks materials shall apply to this and other Clauses of these specifications, if otherwise not specified.

(i) “Topsoil” shall mean the top layer of soil that can support vegetation. It shall include all turf acceptable for turfing.

(ii) “Suitable Material” shall comprise all that is acceptable in the accordance with the Contract for use in the Works and which is capable of being compacted in the manner specified in Clause 309 and 310 to form a stable fill having side slopes as indicated in the Drawing. The material used in fill (except for rock fill) shall not contain rock fragments with dimensions of more than 75 mm.

(iii) "Unsuitable Material" which cannot be considered suitable for canal banks, backfills or embankment and shall mean other than suitable material and shall include:

(a) Material from swamp, marshes or bogs;

(b) Peat, logs, stumps, perishable material, organic clays;

(c) Material susceptible to spontaneous combustion;

(d) Material in a frozen condition;

(e) Clay of liquid limit exceeding 50 and/or plasticity index exceeding 25;

(f) Dispersive soil (Soil with predominance of sodium cations);

Material stated above in (d) if otherwise suitable shall be classified suitable when unfrozen.

(iv) "Rock Fill" shall consist of hard material of suitable size for deposition and compaction as given in Clause 309 and also may comprise rock as defined in Clause 303 and broken stones.

(v) "Well Graded Granular Material" consists of gravel and/or sand conforming to relate IS Codes.

(3) No excavated suitable material other than surplus to requirements of the contract shall be removed from the site except on the direction of the Engineer. Should the Contractor be permitted to remove suitable material from Site to suit his operational procedure, then he shall make good at his own expense any consequent deficit of filling arising therefrom.

(4) Material in surplus to the total requirements of works, and all unsuitable material shall, unless the Engineer permits otherwise, be run to spoil dumps.

(5) Where the excavation reveals a combination of suitable and unsuitable materials the Contractor shall carry out the excavation in such a manner that the suitable materials are excavated separately for use in the works without contamination by the unsuitable materials.

(6) The Contractor shall make his own arrangements for the stockpiling of top-soil and/or suitable material.

(7) At all times the Contractor shall ensure that earthworks are not damaged by weather or traffic. In event of such damage, the Engineer may withdraw approval from the affected works until the Contractor has carried out repairs to restore the works to their original condition.

The cost of all such repairs and any additional testing shall be borne by the Contractor.

(8) Prior to commencement of any earthwork, the work shall be set out where required as specified in Clause 106 following the clearing and grubbing as per Section 200 and Survey of the existing ground shall be conducted jointly by the Contractor and the Engineer. The survey records shall serve as initial measurements for the determination of the final quantities of earthwork performed under the contract.

(9) Works on embankments and/or cutting in areas required for the construction of bridges and other structures shall not be carried out until the Engineer agrees that construction of such structures has sufficiently progressed so that there is no interference or damage to them.

(10) The Contractor shall get approval of the Engineer in respect of method of earthwork, type of equipment to be used, disposal and other details before commencement of the earthwork.

303 CLASSIFICATION OF EXCAVATED MATERIALS

The excavated materials shall be classified under the following categories. The decision of the Engineer in respect of the classification of excavated materials shall be the final and binding upon the Contractor.

Classification: All materials involved in excavation shall be classified by the Engineer in the following manner:

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(1) Soil

This shall comprise topsoil, turf, sand, silt, loam, clay, mud, peat, black cotton soil, soft shale or loose moorum, a mixture of these and similar material which yields to the ordinary application of pick, spade and/or shovel, rake or other ordinary digging implement. Removal of gravel or any other nodular material having dimension in any one direction not exceeding 75 mm occurring in such strata shall be deemed to be covered under this category.

(2) Gravel Boulder Mixed Soil (GBM Soil)

Gravel Boulder Mixed (GBM) soil refers to a type of soil composition that contains a mixture of gravel, cobbles, and other materials. It is a coarse-grained soil type that typically has a higher percentage of larger particles such as gravel and cobbles compared to finer particles like sand or silt. GBM soil is commonly found in areas with rocky or mountainous terrains where weathering and erosion have led to the accumulation of large-sized particles. It is often challenging to work with GBM soil due to its coarse nature, which can affect construction as well as excavation activities. This shall comprise topsoil mixed with gravel less than 75mm and cobbles not more than 300 mm and similar material which yields to the ordinary application of pick, spade and/or shovel, rake or other digging equipment (Cobbles pass a 300-mm equal to 12-inch square opening but are retained on a 75-mm sieve whereas boulders are too large to pass a 300-mm square opening).

(3) Dispersive Clay

Dispersive soil refers to a type of soil composition that have a preponderance of sodium cations. This soil is not suitable for construction of canal in cutting or in embankment and for construction of any type of hydraulic structures. Dispersive clay soil erodes in the presence of flowing water when individual clay platelets are split off and carried away. The hydraulic structures including irrigation/drainage canal constructed in dispersive soil fail by piping. Using dispersive clay soils in irrigation/drainage canal construction, hydraulic structures, embankment, dams, or other structures such as roadway embankments can cause serious engineering problems if these soils are not identified and used appropriately with due treatment. Problems due to dispersive soil is worldwide, and structural failures attributed to dispersive soils have occurred in many countries. The principal difference between dispersive clays and ordinary erosion resistant clays appears to be the nature of the cations in the pore water of the clay mass. Dispersive soil has predominance of sodium cations whereas ordinary clays have a preponderance of calcium, potassium, and magnesium cations in the pore water. Dispersive clays have not been definitively associated with any specific geologic origin but most have been found as alluvial clays in the form of slope wash, lakebed deposits, loess deposits, and flood plain deposits. Dispersive clay soils, which are available in red, brown, gray, yellow, or various combinations of these colors look like ordinary clay and hence cannot be distinguished by naked eyes. Dispersive clays cannot be identified by the standard laboratory index tests such as visual classification, grain size analysis, specific gravity, or Atterberg's limits either and, therefore, other laboratory tests such as the crumb test, the double hydrometer test, the pinhole test and chemical test have been devised for this purpose.

(4) Ordinary Rock (not requiring blasting)

This shall include rock types such as laterites, shales and conglomerates, varieties of limestone and sandstone etc., which may be quarried or split with crow bars, also including any rock which in dry state may be hard, requiring blasting but which, when wet, becomes soft and manageable by means other than blasting. It shall also include compact moorum or stabilized soil requiring grafting tool or pick or both and shovel, closely applied; gravel and cobble stone having maximum dimension in any one direction between 75 and 300 mm; lime concrete, stone masonry in lime mortar and brick work in lime/cement mortar below ground level, reinforced cement concrete which may be broken up with crow bars or picks and stone masonry in cement mortar below ground level; and bounders which do not require blasting having maximum dimension in any direction of more than 300mm, found lying loose on the surface or embedded in river bed, soil, talus, slope wash and terrace material of dissimilar origin.

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(5) Hard Rock (using breaker or requiring blasting)

This shall comprise:

(i) any rock or cement concrete for the excavation of which the use of mechanical plant and/or blasting is required;

(ii) reinforced cement concrete (reinforcement cut through but not separated from the concrete) below ground level; and

(iii) Boulders requiring blasting.

(6) Hard Rock (blasting prohibited)

Hard rock requiring blasting as described under (5) but where blasting is prohibited for any reason and excavation has to be carried out by chiseling, wedging or any other agreed method.

(7) Marshy Soil

This shall include soils like soft clays and peats excavated below the original ground level of marshes and swamps and soils excavated from other areas requiring continuous pumping or bailing out of water.

(8) Authority for classification:

The classification of excavation shall be decided by the Engineer and his decision shall be final and binding on the Contractor. Merely the use of explosives in excavation will not be considered as a reason for higher classification unless blasting is clearly necessary in the opinion of the Engineer.

304 EXPLOSIVES AND BLASTING

(1) General

The procurement, transportation, storage, use, account and disposal of balance and defective explosive materials shall be strictly as per prevalent laws and ordinances applicable to the work site. Should there be any discrepancy found between procedures described hereunder and the prevalent laws and ordinance, the later shall supersede.

Blasting shall be carried out in a manner that completes the excavation to the Lines indicated on the Drawing or as directed by the Engineer, with the least disturbance to adjacent material. It shall be done only with the written permission of the Engineer.

The Contractor shall adopt such method that is consistent with the safety and job requirements. Prior to starting any phase of the operation, the Contractor shall provide information describing pertinent blasting procedures, dimensions and notes.

(2) Material, Tools and Equipment

All the material, tools and equipment used for blasting operations shall be off approved type. The Engineer may specify the type of explosives to be allowed in special cases. The fuse to be used in wet locations shall be water-resistant and shall remain unaffected when immersed in water for 30 minutes. The rate of burning of the fuse shall be uniform and definitely known to permit such a length being cut as shall permit sufficient time to the firer to reach to a safe place before explosion takes place. Detonators shall be capable for giving effective blasting of the explosives. The blasting powder, explosives, detonators, fuses, etc., shall be fresh and not damaged due to dampness, moisture or any other cause. They shall be inspected before use. The damaged articles, if any, shall be discarded totally and removed from the site immediately.

(3) Personnel

The blasting operation shall remain in the charge of competent and experienced blaster with legal license and thorough knowledge of handling explosives and blasting operations.

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(4) Blasting Operations

Explosives shall be used in the quantities and manner recommended by the manufactures. The written permission of the Engineer shall be obtained for each location or series of locations where the Contractor wishes to use more than 5 kg of explosives in one series of blast. Such permission shall not any way relieve the Contractor of his liabilities under the Conditions of Contract.

The blasting shall be carried out during fixed hours of the day preferably during the mid-day luncheon hour or at the close of the work as ordered in writing by the Engineer. The hours shall be made known to the people in the vicinity. All the charges shall be prepared by the blaster only.

The Engineer must be notified at least 24 hours in advance on any blasting operation. When blasting is to be carried out, the Contractor shall determine the danger zone likely to be created, and shall ensure that all personnel, vehicles and livestock are clear of the zone before and during the blast. In settled areas, the Contractor shall take steps to avoid damage to property from flying rock by using blasting mats or other suitable blanketing materials.

The Contractor shall notify each public utility organization/company having structures in proximity to the site to the work of his intention to use explosives. Such notice shall be given sufficiently in advance to enable the companies to take such steps as they may deem necessary to protect their property from injury.

Danger red flags shall be displayed prominently in all directions during the blasting operations. The flags shall be planted 200 m from the blasting site in all directions. People, except those who actually light the fuse, shall be prohibited from entering this area, and all persons including workmen shall be excluded from the flagged area at least 10 minutes before the firing, a warning siren being sounded for the purpose.

The charge holes shall be drilled to required depths and at suitable places. Blasting shall be as light as possible consistent with thorough breakage of the material necessary for economic loading and hauling. Any method of blasting which leads to overshooting shall be discontinued. Not more than 10 charges shall be prepared and fired at a time. The man in charge shall blow a siren in a recognized manner for cautioning the people. The charges shall be lighted by the blasters only. The blaster shall count the number of explosions. He shall satisfy himself that all the charges have been exploded before allowing the workmen to go back to the work site.

After blasting operations, the Contractor shall compact the loose residual material and replace any material excavated below the designed canal bed level or foundation level with suitable material, compacted to the specified density.

When forming final cut faces, pre-split blasting techniques shall be carried out to ensure that blasting damage to the cut face is minimized. Details of the pre-splitting technique to be used shall be notified to and approved by the Engineer at least 24 hours in advance of the blasting operation.

(5) Misfire

In case of misfire, the following procedure shall be observed:

(a) Sufficient time shall be allowed to account for the delayed blast. The blaster shall inspect all the charges and determine the missed charge.

(b) If it is blasting powder charge, it shall be completely flooded with water. A new hole shall be drilled at about 450 mm from the old hole and fired. This should blast the old charge. Should it not blast the old charge, the procedure shall be repeated till the old charge is blasted.

(c) In case of charges of gelignite, the blaster shall gently remove the tamping and the primer with the detonator. A fresh detonator and primer shall then be used to blast the charge. Alternatively, the hole may be cleared of 30 mm of tamping and the direction then ascertained by placing a stick in the hole. Another hole may then be drilled 150 mm away and parallel to it. This hole shall then be charged and fired when the misfired hole should explode at the same time. The blaster shall at once report to the Contractor's office and the Engineer all cases of misfire, the cause of the same and what steps were taken in connection therewith.

(d) If a misfire had been found to be due to defective detonator or gelignite/dynamite, the whole quantity in the box from which defective article was taken must be sent to the authority as directed by the Engineer for inspection to ascertain whether all or art of the remaining materials in the box are also defective.

(6) Account

A careful and day to day account of the explosive shall be maintained by the Contractor in an approved register and manner which shall be open to inspection by the Engineer at all times. Records must be kept by the Contractor of all drilling and blasting operations showing holes diameters and depths, drilling pattern, explosive charge and type per hole, detonator delay times and total charge per blast. These records must be submitted to the Engineer on completion of charging.

305 EXCAVATION IN CUTTING

(1) Cleaning and grubbing shall be performed as specified in Section 200.

(2) While executing excavations, the Contractor shall take adequate precautions against soil erosion and water pollution.

(3) All suitable excavated materials shall be used in construction of the canal banks/embankment to the extent as required.

(4) Hauling of material from cutting or borrow pits to embankments, other areas of fill shall proceed only when plant or labour is operating at the place of deposition to ensure that adequate spreading and compaction of material can take place.

(5) Over-excavation shall not be permitted. Any excess depth excavated below the canal bed level, side slopes or formation levels as specified shall be made good by the Contractor at his own expense by backfilling with suitable material of similar characteristics to those of moved materials with compaction as specified in Clauses 309 and 310.

(6) The slopes of cutting shall be cleared of all rock fragments which move when prized by a crowbar, unless otherwise directed by the Engineer. Where the Engineer considers that the slope, immediately after dressing, shall not be permanently stable, he shall direct the Contractor as to the stabilization measures required. The Contractor shall carry out these measures soon after Engineer's instruction.

When completed, the excavation slopes shall be true to the lines and levels as shown on the Drawing or directed by the Engineer. When completed, no point on slopes shall vary from the designated slopes by more than 150 mm measured at right angles to the slope, except where excavation is in rock, no point shall vary more than 300 mm from the designated slope.

(7) If slips, slides, over breaks or subsidence occur in cutting, they shall be removed. Adequate precautions shall be taken to ensure that during construction, the slopes are not rendered unstable or give rise to recurrent slides after construction.

(8) If water is encountered in excavations due to seepage, springs, or other causes such as marshy soil, it shall be removed by suitable diversions or bailing out and the excavation shall be kept dry. The drained water shall be discharged into suitable outlets as not to damage to the works, crops or any other property. If any such damage is caused due to any negligence of the Contractor, it shall be the sole responsibility of the Contractor to repair/restore to the original condition at his own cost or compensate for the damage.

(9) Stones encountered during excavation/cutting of soil shall be removed and disposed as directed by Engineer. Removal of stone and their subsequent disposal shall be treated as separate item if mentioned in the BoQ and shall be paid at unit rate provided in the BoQ.

306 EXCAVATION BELOW CANAL BEDS AND EMBANKMENTS

(1) Where any unsuitable material below the natural ground level under proposed canal banks or embankments is required to be excavated, it shall be removed to such depth and over such areas as shown on the Drawing or as directed by the Engineer. The excavated materials shall be disposed off as indicated on the Drawing or directed by the Engineer. The resultant excavation shall be backfilled with suitable material and shall be levelled and compacted to the density as specified for forming of the embankments.

Nevertheless, if such backfill has to be carried out in standing water, the Contractor shall use only an approved non-plastic well-graded granular material having maximum size of not greater than 75 mm. Such materials may be deposited in water without use of compaction equipment.

(2) Where shown on the Drawing, approved, graded stones having size from 380 mm to 150 mm and containing not more than 10 percent, below 150 mm in size shall be placed directly on the natural occurring unsuitable material. This type of rock fill material shall be deposited in accordance with the requirements of Clause 309 and compacted as per Clause 310.

(3) If after the removal of material as specified in Sub-clause 306 (1), the Contractor allows the materials so exposed to reach a condition where compaction of back filling is impracticable, he shall make good at his own expense either by additional excavation and filling in the manner specified in this Clause, or by waiting until the condition of the exposed material is fit to receive the approved backfill.

307 EXCAVATION FOR FOUNDATION

(1) Slope

Excavation shall consist of the removal of material for the construction of foundations for drainage structures, retaining walls, head walls, cut off walls, headworks, regulators, weirs, barrages, aqueducts, pipe outlets, culvert, bridges and other similar structures to the lines and dimensions shown on the Drawing or as instructed by the Engineer in accordance with the requirements of these specifications. The work shall include construction of the necessary cofferdams and cribs and subsequent removal of all necessary sheeting, shoring, bracing, diversion of water/flow, draining and pumping, the removal of all logs, stumps, grubs and other deleterious matters and obstructions necessary for placing the foundation; trimming bottoms of excavations; and cleaning up the site and the disposal of all surplus material.

(2) Excavation

Excavation shall be taken to the length and width of the lowest step of the footing, and the sides shall be left to plumb where the nature of soil allows it. Where the nature of soil or the depth of the trench does not permit vertical sides, the Contractor at his own expense shall put up necessary shoring, strutting and planking or cut slopes to a safer angle or both with due regard to the safety of personnel and works and to the satisfaction of the Engineer.

The depth to which the excavation is to be carried out shall be as shown on the Drawing or as directed by the Engineer.

Where blasting is to be restored to, the same shall be carried out in accordance with Clause 304.

(3) Dewatering, Diversion of Flow and Protection

Normally, open foundation shall be laid dry. Where water is encountered in excavation due to stream flow, seepage, spring, rain or other reasons, the Contractor shall take adequate measure such as bailing, pumping, constructing diversion channels, drainage channels, bunds, cofferdams and other necessary works to keep the foundation pit or trenches dry, when so required and to protect the green concrete/masonry against damage by erosion, failure of cut slope or sudden rising of water level. The methods to be adopted in this regard and other details thereof shall be left to the choice of the Contractor,

but subject to approval of the Engineer. Approval of the Engineer shall, however, not relieve the Contractor of the responsibility for the adequacy of the Engineer shall, however, not relieve the Contractor of the responsibility for the adequacy of dewatering and protection arrangements and for the quality and safety of the works.

Where cofferdams are required, these shall be carried to adequate depths and heights, be safely designed and constructed and be made as watertight as is necessary for facilitating construction to be carried out inside them. The interior dimensions of the cofferdams shall be such as to give sufficient clearance for the construction and inspection and to permit installation of pumping equipment, etc., inside the enclosed area.

Cofferdam sheet-pilling shall be carried down well below the bottom of the pile caps or footings, but without interference with any bearing piles. Cofferdams shall be rigidly constructed and efficiently braced to withstand external pressures when water is pumped out. Sheeting shall be reasonably watertight and all appreciable leaks encountered during the operations shall be stopped so that construction of pile caps can be carried out in the dry. The Contractor shall rectify any cofferdam which, for any reason, has moved, tilted, or changed its shape and/or size.

Pumping form, the interior of any foundation enclosure shall be done in such a manner as to preclude the possibility of the movement of water through any fresh concrete. No pumping shall be permitted during the placing of concrete or for a period of at least 24 hours thereafter, unless it is done from a suitable sump and is separated from the concrete work by a watertight wall or other similar means.

At the discretion of the Contractor, cement grouting or other approved methods may be used to prevent or reduce seepage and to protect the area of excavation.

The Contractor shall take all precautions in diverting flow and in discharging the drained water as not to cause damage to the works, crops or any other property. If any such damage is caused due to any negligence of the Contractor, it shall be the sole responsibility of the Contractor to repair/restore to the original at his own cost or compensate for the damage.

(4) Preparation of Foundation Base

The bottom of the foundation pit shall be levelled both longitudinally and transversely or stepped as directed by the Engineer. Before footing is laid, the surface shall be slightly watered and rammed, if surface is not wet. In the event of excavation having been made deeper than that shown on the Drawing or as otherwise ordered by the Engineer, the extra depth shall be made up with concrete or masonry of the foundation grade at the cost of the Contractor. Ordinary filling shall not be allowed for the purpose of bringing the foundation to level. When rock or other hard strata is encountered, it shall be freed of all soft and loose materials, cleaned and cut to firm surface either levelled or stepped as directed by the Engineer. All seams shall be cleaned out and filled with cement mortar or grout to the satisfaction of the Engineer. In the case of rock excavation, annular space around footing shall be filled with concrete of grade M 10 up to top level of rock.

After the excavation is completed, the Contractor shall inform the Engineer to that effect and no footing, bedding materials or structures shall be placed until the Engineer has approved the depth and the suitability of foundation material.

If, at any point, in any foundation excavation, material unsuitable for foundations is encountered, the Contractor shall, if so instructed by the Engineer, shall remove all such materials and refill with suitable materials thoroughly compacted by tamping or rolling in layers of not more than 150mm thick each.

(5) Slips and Blows

If there are any slips or blows in the excavation, these shall be removed by the Contractor at his own cost.

(6) Public Safety

Where required, trenches and foundations pits shall be securely fenced, provided with proper caution signs and marked with red lights at night to avoid accidents as per Sub- clause 103 B.

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The Contractor shall take adequate protective measures to see that the excavation operations do not affect or damage adjoining structures.

(7) Removal of Cofferdams

All cofferdams with all temporary sheeting and bracing shall be removed by the Contractor after the completion of the substructure unit. The removal shall be carried out in such a manner as not to disturb or damage the finished concrete. However, sheet pilling below the top of the pile caps may be left in place at the Contractor's option and expenses.

No bracing, no other material shall be left in cofferdam in such a way as to extend into the concrete of the structure.

Cofferdams located in a stream or lake and within the limits of low water shall be removed to the elevation of the stream or lakebed, except that in established navigation channels, they shall be removed to an elevation at least 600 mm below the established bottom of the channel.

308 REFILLING OF FOUNDATION PITS AND TRENCHES, REMOVAL OF SUPPORTS AND FILLING TO STRUCTURES

Refilling of foundation pits and trenches shall consist of previous backfill and/or common backfill as shown on the Drawing or as directed by the Engineer.

(1) Materials

(a) Pervious Backfill

Unless otherwise specified in the contract, it shall be of gravel, crushed gravel, crushed rock, natural sands, manufactured sands or combinations thereof. It shall conform to the grading limits set out in Table 3.1.

Table 3.1: Grading Limits of Pervious Backfill

Sieve Size (mm)	Percentage Passing by Weight
40	100
10	45-100
2.36	25-80
0.60	8-48
0.075	0-6

(b) Common Backfill

Common backfill materials other than pervious backfill shall be suitable material as defined in Sub-clause 302 (2).

(2) Method of Filling

Backfilling material shall be placed and compacted in layers in compliance with the requirements of Clause 310. Any temporary supports, shoring or other protective measures used for the excavation shall be removed progressively as backfilling proceeds, unless otherwise specified in the Contract or directed by the Engineer. Backfill shall be placed in a manner that does not impose excessive or uneven loads on the structure or adversely affect its stability. Backfilling adjacent to structures shall be carried out uniformly on both sides, where practicable, to avoid differential loading or displacement. The surfaces of excavations against which backfill is to be placed shall be stepped or prepared as directed by the Engineer to ensure proper bonding between the existing ground and the backfill. Backfilling around hydraulic structures, retaining structures, culverts, pipe outlets, headworks and other structures shall be carried out carefully and, in a sequence, approved by the Engineer. Where the stability of a structure depends on the completion or strength of adjoining structural works, backfilling shall not commence until the required strength and stability have been achieved and approval has been obtained from the Engineer.

309 FORMING OF EMBANKMENT AND OTHER AREAS OF FILL

(1) The work shall consist of the construction of canal banks and embankment, filling on other areas and backfill not specified elsewhere by providing material as specified or approved by the Engineer, placing, compacting and shaping to lines, levels, grades and cross sections as shown on the Drawing or as directed by the Engineer. The maximum size of the coarse material in the mixture shall not exceed 75 mm for general earth fill.

(2) The limits of embankment shall be built sufficiently wider than the design dimension to facilitate in achieving required compaction nearby outer faces of the embankment. The surplus material shall be trimmed to conform the specified side slopes and width of the embankment.

(3) Where necessary, the original ground shall be scarified, mixed with water, levelled and then compacted so as to achieve the density mentioned in Clause 310. Where necessary, embankment foundations shall be excavated/furrowed and brought under OMC and re-compacted in layers of 150 mm each in order to achieve the required level of compaction.

(4) Canal banks and embankments shall be built up evenly over the entire width and shall be maintained at all times with a sufficient camber to enable surface water to drain rapidly from them. Damage to compacted layers by constructional or other traffic shall be made good by the Contractor.

(5) The natural moisture content and the optimum moisture content of the material to be placed in the embankment shall be checked before start of the placing material. If found to be out of the specified limits, the same shall be made good. Where water is required to be added in such constructions, water shall be sprinkled from a water tanker fitted with sprinkler capable of applying water uniformly with a controllable rate of flow to variable widths of surface but without any flooding. Water shall be sprinkled uniformly and thoroughly mixed in soil by blading or harrowing until a uniform moisture content as specified is obtained.

Moisture content, checked in accordance with IS 2720 (Part 2), at the time of compaction shall be between 90% and 105% of the Optimum Moisture Content as determined in accordance with IS 2720 (Part 8).

If the material delivered for fill/backfill is too wet, it shall be dried by aeration and exposure to sun, till the moisture content is acceptable for compaction. Should circumstances arise, where owing to wet weather, the moisture content cannot be reduced by the above procedure, compaction work shall be suspended.

If the material deposited as fill subsequently reaches a condition such that it cannot be compacted in accordance with the requirements of the specifications the Contractor shall

(i) Make good by removing the material off the embankment and placing suitable material; or

(ii) Make good by tipping it elsewhere until it is in a suitable physical condition for re-use; or

(iii) Make good the material by mechanical or chemical means to improve its properties acceptable to the Engineer.

(6) Where fill is required to be constructed across water logged or soft clayey ground that displays excessive movement under normal constructional equipment, it may be necessary to construct a capping layer.

(7) Rock use in rock fill embankments shall be deposited in horizontal layers not exceeding 450 mm each extending up to the full width of the embankment.

Material shall be spread, levelled and compacted in accordance with Clause 310. Each layer shall consist of reasonably graded rock and all surface voids shall be filled with broken fragments before the next layer is placed. The top surface and side slopes of embankments so formed shall be thoroughly blinded with approved well graded material to seal the surface

(8) While filling embankment up to or over culverts or pipe drains, and where required in the contract, up

to bridges, the Contractor shall bring the embankments up equally on both sides. In rock fill embankments the rock shall be carefully packed for such distance from the structure as is described in the contract.

Where provision of filter membrane is specified behind structures, the same shall be laid in layers simultaneously with the laying of fill material.

310 COMPACTION OF EMBANKMENT AND OTHER AREAS OF FILL/BACKFILL

(1) The Contractor shall obtain the Engineer approval of all fill layers before covering with subsequent layers.

(2) All fill shall be compacted to the depth and degree of compaction as specified in Table 3.2 or as shown on the Drawing.

Table 3.2: Compaction Requirements

Location	Depth below Formation Level (mm)	Minimum Compaction (%MDD Heavy Compaction
Canal Embankment, Riverbank Embankment	0-300	95
Canal Embankment, Riverbank Embankment	>300	93
All other fills and backfill not separately specified		95

(3) Each layer of rock used to fill in embankments shall be spread and levelled in accordance with Sub-clause 309 (7) and systematically compacted.

(4) Layers of material other than rock fill shall not exceed 150 mm compacted depth unless and until the Contractor can demonstrate to the satisfaction of the Engineer that he can successfully Compact layers of a greater thickness.

(5) Each layer shall be constructed in lengths suitable to the compaction and working methods used. Materials of each layer shall be thoroughly mixed with water as necessary to facilitate its compaction to the specified density.

(6) In cut areas, the subgrade shall be processed as necessary and compacted to the depth and compaction requirements as given in Table 3.2. In the event that the Contractor is unable to achieve the minimum compaction requirements below formation level he shall excavate and re compact in layer as necessary.

(7) Where it may be impracticable to use conventional rollers, the compaction shall be carried out by appropriate mechanical means such as small vibratory rollers, power rammers or plate compactor. Care shall be taken to ensure that the compaction equipment does not hit or come too close to any structural member so as to cause any damage to it.

311 COMPACTION TRIALS

(1) Before commencing filling embankment and from time to time as may be considered necessary by the Engineer, the Contractor shall carry out compaction trials in the presence of the Engineer on each of the main types of soil and rock fill to be used and compacted in the Works. He shall carry out all necessary laboratory and field testing as required by the Engineer and shall submit to the Engineer the results of all tests.

The trial procedure shall include the compaction of trial areas selected by the Engineer. The surface of

each area shall first be well compacted to the satisfaction of the Engineer. Each type of material being used shall be compacted in equal layers at uniform but differing moisture contents to a predetermined number of passes using the Contractor's proposed compaction equipment.

(2) Following completion of the compaction trials, the Contractor shall submit to the Engineer, for his approval, his proposals for the compaction of each type of material to be encountered in the Works and its degree of compaction specified. The Contractor's proposals shall include reference to the types of equipment, the operating weights and type pressure, the methods of adjusting the moisture content, the number of passes and the loose depth of each layer.

If, in the opinion of the Engineer, the results of the compaction trials indicate that the Contractor's proposed plant and methods shall achieve the densities as specified, the Engineer shall approve the same. Otherwise, the Contractor shall submit, in writing, proposals for modifying the plant and/or methods and shall, if the Engineer so requires, compact further trial areas in accordance with these modified proposals until the Engineer approves of Contractor's proposals.

(3) When compaction of earthworks is in progress, the Contractor shall adhere to the compaction procedure approved by the Engineer.

(4) Notwithstanding the Engineer's approval of any of the Contractor's plant or methods, the Contractor shall at all times be solely responsible for executing the earthworks in accordance with the Specifications and the Drawing.

312 BENCHING

(1) Where canal banks or embankments are to be constructed on hill slopes or slopes with more than or equal to 1 vertical to 4 horizontal slopes, benches with vertical and horizontal faces shall be cut into the existing slope (including rock) and the embankment shall be built up in successive layers. Where the cross slope is less than 1 vertical to 4 horizontal slope (other than rock) shall be loosened by scarifying to a depth of not less than 100 mm measured perpendicular to the slope, to ensure a good bond between the embankment and the embankment foundation. Material which has been loosened shall be covered with the first layer and compacted to the specified density simultaneously with the first layer of embankment material placed.

(2) Where existing canal bank or embankment are to be widened or included in a new embankment and slopes are not more than 1 vertical to 4 horizontals, the slope of the existing embankment shall be scarified to a depth of not less than 100 mm to ensure bond. Where the slope is less than 1 vertical to 4 horizontals, continuous horizontal benches, each at least 300 mm wide, shall be cut in existing slopes and the widened embankment shall be built up in successive layers of thickness of 150 mm to the level of old existing embankment top.

Where the width of the widened portions is insufficient to permit the use of heavy rollers, compaction to the specified density shall be carried out with the help of small vibratory roller/plate compactor/rammer or other approved methods.

313 EARTHWORKS TO BE KEPT FREE OF WATER

By providing temporary water course, ditches, drains, pumping or other means the Contractor shall arrange for the rapid dispersal of water from the areas of earthworks. Where practicable the water shall be discharged into permanent outfall for the drainage system. Adequate means for trapping silt shall be provided on temporary systems while discharging into permanent drainage systems.

314 WATERCOURSES

Excavations carried out in the diversion, enlargement, deepening or straightening of watercourses shall

include the operations of any necessary trimming of slopes, grading of beds, disposal of excavated materials and pumping, tampering works and materials necessary for dealing with the flow of water.

315 FILLING EXISTING WATERCOURSES

Where watercourses have to be diverted from the sites of embankments or other works, the original channels shall be cleared of all vegetable growths and soft deposits and filled in with suitable materials deposited and compacted as specified in Clauses 309 and 310.

316 PROCESS CONTROL

(1) Throughout the works the Contractor shall perform tests to determine the suitability and compaction characteristics of soils to be used. The maximum dry density (MDD) and Optimum moisture content (OMC) test shall be conducted in accordance with IS 2720 Part 8 as specified in Table 8.8.

(2) In addition to the foregoing tests, the Contractor shall carry out field density tests on the compacted fill materials in accordance with IS 2720 part 28/29. As specified in Table 8.8 and shall be carried out in each layer, including original ground surface on which embankment is to be constructed. If the result of any test shows that the minimum specified density has not been achieved, further compaction shall be executed to the area concerned and the layer re-tested. Unless the test results are satisfactory, the addition of another layer shall not be allowed.

(3) The Contractor shall carry out tests for determination of moisture content at frequent intervals on all materials during the course of compaction as per Sub-clause 309 (5) to ensure that the requirements of Clause 310 are met with.

317 TEST FOR DISPERSIVE SOIL

Dispersive clays cannot be distinguished from nondispersive clays by conventional index tests such as gradation, Atteberg's limits, or compaction characteristics. The five laboratory tests most generally performed to identify dispersive clays are the crumb test (as specified in USBR 5400), the double hydrometer test(as specified in USBR 5405), the pinhole test (as specified in USBR 5410), the test of dissolved salts in the pore water, and the ESP (exchangeable sodium percentage) based tests.

However, results from the individual tests often do not agree, and the pinhole test is considered the most reliable since it is a direct physical test. It is emphasized that all of the tests should be performed on each soil sample for the most complete information and most reliable identification.

The primary requirement for taking soil samples in the field for any method of dispersive testing whether in the United States or elsewhere is to ensure that there is no moisture loss from the sample. Samples should be shipped to the laboratory in airtight containers. It is important that all soil specimens be maintained and tested at their natural water content since drying, especially oven drying, may alter dispersive characteristics.

318 LANDSLIDE CLEARANCE

This Clause covers removal of landslides, slips, debris and other obstructions affecting canals, canal banks, embankments, river-training works and associated facilities.

The work may include:

- removal of earth, rock, debris and other materials deposited within the canal section or on canal banks;
- removal of fallen trees, branches and other obstructions;
- trimming and restoration of unstable or damaged canal slopes and embankments;

- restoration of the canal bed, banks and associated drainage works to the required lines and levels;
- provision of temporary diversion or protection measures where necessary; and
- provision of warning signs, barriers and other safety measures where required.

The Contractor shall dispose of removed material at locations approved by the Engineer and shall take measures to prevent recurrence of erosion or slope failure where directed.

319 DESILTING OF CANAL

(1) General

Desilting of Canal also known as silt clearance is required to clear the silt deposited in canal bed and slope due to canal operation. This operation is inevitable to maintain the canal section and regulate the canal flow in capacity.

(2) Construction

The silt deposited in the canal bed and slope shall be cleared manually or mechanically using excavator. Silt shall be cleared to maintain the true and uniform design shape (bed width and slope gradient) of the canal avoiding any residual undulation in order to the flow capacity. Silt excavated shall be disposed beyond the canal section. Silt can be deposited on outer slope of the canal if permitted by the Engineer.

320 MEASUREMNT

(1) The quantities of the various classes of earthwork to be measured for payment under the contract shall be limited to the lines, grades, slopes and dimensions shown on the Drawing or as determined by the Engineer.

(2) Except for foundation, all excavation including side drains, filling and backfilling compacted in place shall be measured in cubic meters by the average end area method as computed from the original and final cross-sections of the completed work. The distance between two end areas shall be the distance measured along central line of the canal/embankment. Where due to changed conditions, or the nature of a particular operation, or for any other reason, it is impossible or impractical to measure the quantities by means of average end areas, the Engineer shall compute the quantities by a volumetric method, if in his opinion, it is the best suited method to obtain an accurate determination.

No separate measurement for payment shall be made for excavation made on borrows, quarries, temporary works or in places outside the scope of permanent works specified in the contract.

Foundation excavation for structures shall be measured in cubic meters irrespective of all classes of materials except rock encountered. The quantities to be measured shall be the net cubic content of the voids formed by the removal of the materials enclosed between the bottom of the footing and existing ground level by a surface generated by vertical lines passing through the periphery of the bottom of the footing. No payment shall be made for any excavation other than the limited excavation described above. Excavation over increased width or length, cutting of slopes, removal of slides, shoring, shuttering and planking shall be deemed as convenience for the Contractor in executing the work and shall not be measured and paid for. Backfill to be measured shall be limited to this void only with due consideration of the nature of the structure.

Foundation excavation in rock shall be deemed to be covered by the rate for rock excavation.

(3) Consumption of explosive materials, levelling, watering and compaction of original ground, construction of coffer dams, pumping out water and other ancillary and incidental works necessary to complete the item as per this specification shall not be measured for payment. They are deemed included in the measurement of the item concerned.

(4) Unless stated otherwise, Lead and Lift of excavated materials for disposal shall not be measured for

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payment. They are deemed to be included in the quoted rates for the earthwork operations irrespective of haulage distance and lift height.

(5) If the material obtained from canal excavation is used fully or partially in banks/embankments filling, the quantities for excavation and filling shall be computed as below.

The quantities of excavation and filling of the distances under reference shall be calculated separately adopting the method described as above in this Section. The computed quantity of filling shall be measured in filling while difference between quantities of excavation and filling shall be measured in excavation. The same excavated material shall not be measured both in excavation and filling.

321 PAYMENT

(1) Various classes of earthworks i.e. excavation, filling, backfilling, additional leads and lifts measured as described above shall be paid at contract unit rate of the respective item.

The contract unit rates shall be the full and the final compensation to the Contractor as per Clause 115 and for the cost of:

(i) Arrangement of land as source of materials as much as needed.

(ii) Process Control tests.

(iii) Execution of all relevant operations described above in this Section and necessary to complete the item as per this specification.

(2) Foundation excavation for structures, measured as described above, shall be paid for at the contract unit rate for all classes of excavation. The contract unit rate for foundation excavation shall be the full and the final compensation to the Contractor as per Clause 115 and for the cost of carrying out the required operations to excavate to the lines and levels as required by the Drawing or as directed by the Engineer.

SECTION 400: COLLECTION AND PROVIDING OF MATERIAL

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401 GENERAL

Unless otherwise stated in the contract, it is the responsibility of the Contractor to select the sources of materials (Fine aggregate, coarse aggregate (Riverbed round material, crushed/broken aggregate), Rubble stone etc. for concrete, masonry or other works. Such sources shall be designated as rock quarries and natural riverbeds. Quarries shall be identified prior to the commencement of the contract. The Contractor shall propose quarries from the identified sites or may propose any new sites, and the Engineer shall instruct the Contractor as to which of these shall be utilized for the extraction of suitable materials to be used in the works during the contract.

402 DEFINITIONS

a. Rock Quarry

A rock quarry is an open surface working in massive rock from which stone is removed by drilling and blasting for use in the works.

b. Quarry

A quarry is an open surface working from which stone, aggregate, gravel, sand or other suitable construction materials are extracted, processed or collected for use in the works.

c. Alluvial Deposit

An alluvial deposit is a site where gravel, sand and aggregate of alluvial origin are extracted for use in the works.

d. Riverbed

A riverbed is a bed of natural river from where suitable materials like sand, coarse aggregates of different grades, pebbles, stones, etc. are collected for use in different works.

e. Borrow Area

A borrow area is an area from which suitable soil, earth, gravel or other material is excavated for use as canal embankment, guide bunds, river training works, backfill or other filling works.

f. Stockpile Area

A stockpile area is an area where material such as topsoil, fill material, gravel or aggregate is stockpiled prior to use in the works.

g. Spoil Area

A spoil area is a site upon which surplus or unsuitable materials arising out of works are dumped within or beyond the canal designed sectional area as indicated on the Drawing or directed by the Engineer.

403 LOCATING MATERIAL SOURCES

a. The Contractor shall be responsible for locating all material sources and for the acquisition or renting of all land required for quarries areas and for access thereto as specified in the Contract.

b. The location and size of quarry proposed by the Contractor shall be subject to the approval of the Engineer.

c. The Contractor shall submit for the Engineer's approval full information regarding the proposed location of the material source not later than 30 days after issue of the work order to commence the works.

The Contractor's proposal shall include but not limited to the following;

i. A site plan in a suitable scale of proposed location of material source

ii. Laboratory test results of material as per requirement mention in the related Section of the specification

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iii. Other relevant information

d. Where the Contractor uses a quarry identified or instructed by the Engineer, he shall obtain the Engineer's approval of such quarry and of the alignment of the access roads into the quarry or borrow area.

e. Where quarries, available for inspection at the time of the tender, are instructed by the Engineer, the Contractor shall satisfy himself as to the quality and quantity of materials available before providing the information required in this Clause. Should such investigations reveal that there is insufficient suitable material for the use for which such material sources were intended, the Contractor shall immediately inform the Engineer in writing, and the Engineer shall either direct that such sources are extended or that new sources shall be used.

f. When a quarry, alluvial deposit, borrow pit, spoil or stockpile area has insufficient suitable material or area for the use for which it was intended, the Contractor shall propose in writing that either any existing quarry, alluvial deposit, borrow pit, spoil or stockpile area be extended or that a new quarry, alluvial deposit, borrow pit, spoil or stockpile area shall be used. The approval and acquisition of such new or extended quarries, alluvial deposits, borrow pits, spoil or stockpile areas shall be in accordance with all the above provisions of this Clause for the acquisition of the original quarries, alluvial deposits, borrow pits, spoil or stockpile areas.

404 SAFETY AND PUBLIC HEALTH REQUIREMENTS

The Contractor shall comply with the prevalent laws and Regulations including those of the Local Authority regarding public health and safety in respect of the operation of quarries and in the absence of, or in addition to such Regulations, shall comply with the following conditions:

i. All areas of work, if they are not naturally under water, shall be drained and kept drained where a quarry has been excavated such that it will not drain naturally, it shall be kept pumped dry while being used.

ii. The Contractor shall confine his operations solely to the areas provided and shall demarcate the boundary of the area and erect temporary or permanent fencing as instructed by the Engineer.

iii. Where the height of any face exceeds 1 meter, the Contractor shall provide, erect and maintain at his own expense stock proof fencing and gates to prevent unauthorized access to the top of the working face.

405 ACCESS ROADS

The Contractor shall comply with the provisions of Clause 111 and with the Conditions of Contract with regard to the construction and maintenance of access roads to quarries.

406 SELECTION OF MATERIALS

In case of material to be collected or excavated from quarries, before a quarry is opened, the Engineer shall instruct the Contractor as to the type of material to be excavated/collected and the areas and depth to be covered. The Engineer may require specific operations of equipment according to the characteristics of the raw material and the characteristics of the final product to be obtained in accordance with relevant Section of those Specifications.

Quality of materials to be collected shall be tested according to their use in conformance with the relevant Sections of these Specifications. When the requirements of the final products are not met, the Engineer may require the Contractor to control the quality of the materials.

407 PILING, STAKING AND STORAGE OF MATERIALS

Safe, dry and properly covered storage place shall be used by the Contractor for all materials, particularly for cement. The storage place for cement shall be waterproof and airtight. The floor of the building to be used for storage of cement shall be raised at least 30cm above the ground to prevent absorption of moisture. Cement bags should not be piled/staked to a height more than 2m. Storage of cement in open area may be permitted by the engineer for small works, in which case cement shall be staked on raised

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platform and adequately protected by waterproof covering.

Coarse aggregates shall be stockpiled in a manner and location approved by Engineer. The contractor shall clean and level the place before stockpiling the coarse aggregates at his own cost. Every care shall be taken by the contractor to ensure that there is no segregation during stockpiling. Coarse aggregates shall be staked in a rectangular shape with height not exceeding 1m.

Stones shall be stacked on dry firm ground in a regular heap particularly in rectangular shape not more than 1 m in height.

Bricks shall be stacked on dry firm ground. For proper inspection of quality and ease in counting, the stacks shall be 50 bricks long, 10 bricks high and not more than 4 bricks in width, the bricks being placed on edge, two at a time along the width of the stack. Clear distance between adjacent stacks shall not be less than 0.8 m. Bricks of each truck load shall be put in one stack.

408 MEASUREMENT AND PAYMENT

Unless otherwise stated, measurement of collection of materials, piling / staking of material etc. as described in this section shall be done in units as stated in respective items in the section and payment shall be made as per contract unit rate. The Contract unit rate shall be the full and the final payment to the Contractor as per Clause 112 to complete the work as per these Specifications.

SECTION 500: TRANSPORTATION OF MATERIAL

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502 SAFETY AND PUBLIC HEALTH REQUIREMENTS 5-1
503 ACCESS ROADS 5-1
504 SITE CLEARANCE AND REMOVAL OF TOPSOIL AND OVERBURDEN.....5-1
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501 GENERAL

Transportation of materials shall be done by trucks, labour using doko-tokari, labour using wheelbarrow or mules, as mentioned in this section. The Contractor shall be responsible for the transportation of all materials required for construction, including but not limited to earth, selected fill material, sand, aggregates, rubble stone, masonry stone, rock, concrete materials, filter materials and other materials required for canal works, irrigation structures, drainage works, river training and associated works.

The sources of materials shall be designated as rock quarries, quarries, alluvial deposits and borrow and are defined in Clauses of concerned section. Certain rock quarries, quarries, alluvial deposits, borrow pits may have or have been identified prior to the commencement of the contract and the Engineer shall instruct the Contractor as to which of these shall be utilized for the extraction as natural or suitable materials to be used in the works.

Provisions are included in subsequent Clause of this Specification. Location of quarries, alluvial deposits borrow pits shall be identified and located by the Contractor during the contract. Similarly, stockpile and spoil shall be located by the Contractor subject to the approval of the Engineer.

502 SAFETY AND PUBLIC HEALTH REQUIREMENTS

The Contractor shall comply with the prevalent laws and Regulations including those of the Local Authority regarding public health and safety in respect of the operation of rock quarries, quarries, alluvial deposit, borrow pits, spoil or stockpile areas, and in the absence of, or in addition to such Regulations, shall comply with the following conditions:

i. All work areas that are not naturally underwater shall be drained and kept dry. If a quarry or borrow pit is excavated to a depth where it cannot drain naturally, the Contractor shall keep it pumped dry for as long as it remains in use.

ii. The Contractor shall confine his operations solely to the areas provided and shall demarcate the boundary of the area and erect temporary or permanent fencing as instructed by the Engineer.

iii. Where the height of any face exceeds 1 meter, the Contractor shall provide, erect and maintain at his own expense stock proof fencing and gates to prevent unauthorized access to the top of the working face.

iv. On completion of work temporary fences and all temporary structures shall be demolished and removed. All latrine pits shall be filled in and drained. The site shall be top soiled and left neat and tidy.

503 ACCESS ROADS

The Contractor shall comply with the provisions of Clause 111 and with the Conditions of Contract with regard to the construction and maintenance of access roads to quarries, alluvial deposits, borrow pits, spoil and stockpile areas.

504 SITE CLEARANCE AND REMOVAL OF TOPSOIL AND OVERBURDEN

Unless otherwise specified in the contract or instructed by the Engineer, the Contractor shall clear the sites of all quarries, alluvial deposits, borrow pits, spoil and stockpile areas in accordance with Section 200 but measurement and payment shall be made in accordance with this Section. All existing fences, trees, hedges and other features which the Engineer shall instruct shall not be removed or otherwise dealt with. They shall be protected in accordance with Section 200.

Unless otherwise directed by the Engineer, the Contractor shall remove topsoil and/or overburden from quarries, alluvial deposits, borrow pits and spoil and stockpile areas. The Engineer shall direct whether topsoil shall be stripped and stockpiled separately or shall be excavated and spoiled together with the overburden. If suitable, the Engineer may direct for the use of overburden in the relevant works.

On completion of the work in any quarry, alluvial deposit, borrow pit, spoil or stockpile area the overburden and/or topsoil which has not been used in the works shall be pushed back, spread and landscaped over the area of the quarry, alluvial deposit, borrow pit, spoil or stockpile area. Where topsoil has been stockpiled separately, it shall be pushed back and spared over the quarry, alluvial deposit, borrow pit, spoil or stockpile area after landscaping.

505 SELECTION OF MATERIALS

In case of material to be collected or excavated from quarries/borrow pits, before a quarry, alluvial deposit or borrow pit is opened, the Engineer shall instruct the Contractor as to the type of material to be excavated/collected and the areas and depth to be covered. The Engineer may require specific operations of equipment according to the characteristics of the raw material and the characteristics of the final product to be obtained in accordance with relevant Section of those Specifications.

Quality of materials to be collected or transported shall be tested according to their use in conformance with the relevant Sections of these Specifications. When the requirements of the final products are not met, the Engineer may require the Contractor to control the quality of the materials.

506 HANDLING, LOADING, TRANSPORTATION AND UNLOADING OF MATERIALS

The Contractor shall handle, load, transport and unload all materials in a manner that prevents damage, contamination, segregation, deterioration or loss of material and shall comply with the requirements of the relevant Sections of these Specifications.

Materials shall be properly loaded, secured and transported by suitable means of transport. During transportation, materials shall be adequately covered or protected where necessary to prevent loss, dust generation, contamination and adverse effects due to weather conditions.

Loading and unloading shall be carried out carefully to avoid segregation, breakage, deformation or other damage to the materials. Different types, grades or sources of materials shall be transported and unloaded separately where required.

Materials shall be unloaded only at locations approved or directed by the Engineer and shall be stacked, stockpiled or placed in a manner suitable for inspection and subsequent use. Unloading and temporary storage shall not obstruct or adversely affect the flow of water in natural watercourses, rivers, canals, drains or other hydraulic structures, nor interfere with construction activities or public access.

Any material lost, contaminated, damaged or rendered unsuitable due to improper handling, loading, transportation or unloading shall be replaced by the Contractor at his own cost.

The Contractor shall provide all necessary labour, equipment and temporary arrangements required for safe and proper handling, loading, transportation and unloading of materials.

507 MEASUREMENT AND PAYMENT

Unless otherwise stated, no separate measurement and payment shall be made in respect of all items such as site clearance, overburden and topsoil removal, and access roads to quarries, alluvial deposits, borrow pits, spoil or stockpile areas and reinstatement including landscaping and spreading topsoil in this Section. The Contractor shall be deemed to have allowed the cost of complying all requirements of this Section elsewhere in his rates.

Where the Engineer has instructed that overburden or topsoil will be used in the works, measurement and payment shall be in accordance with the relevant Sections of these Specifications.

Measurement of transportation of other items in this section shall be done in units as described in respective items in the section and payment shall be made as per contract unit rate. The Contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

SECTION 600: BRICKWORKS

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601 SCOPE

This Section covers the furnishing of materials and construction of brick works for structures in accordance with the detail shown on the Drawing and these Specifications or as directed by the Engineer.

602 MATERIALS

(1) Bricks

a) Machine Made Bricks

Machine made Bricks shall be of uniform deep red or copper colour, thoroughly burnt without being vitrified, regular in shape and size and shall have sharp and square sides and edges and parallel faces to ensure uniformity in the thickness of the courses of brickwork. The Brick shall be first class bricks and free from grit and other impurities such as lime, iron and other deleterious salts, conforming NS-1/2035 except that minimum compressive strength when tested flat shall not be less than 8 N/mm^2 for individual bricks and 10 N/mm^2 for average 5 specimens and that the size may be according to local practice with a tolerance of ± 5 percent. These shall be well-burnt, sound, and hard with sharp edges and shall emit ringing sound when struck with a mallet. The average water absorption of the brick samples shall not be more than 15% over the dry weight after immersion in cold water for 24 hours.

b) Chimney Bricks

The Brick shall be uniform first class chimney made bricks and free from grit and other impurities such as lime, iron and other deleterious salts, conforming NS- 1/2035 except that minimum compressive strength when tested flat shall not be less than 8 N/mm^2 for individual bricks and 10 N/mm^2 for average 5 specimens and that the size may be according to local practice with a tolerance of ± 5 percent. These shall be well burnt, sound, and hard with sharp edges and shall emit ringing sound when struck with a mallet. The bricks shall be provided with frogs. The average water absorption of the brick samples shall not be more than 25% over the dry weight after immersion in cold water for 24 hours.

(2) Mortar

(i) Cement Sand Mortar

Cement Sand mortar shall be mixed in proportion of materials as indicated in the contract. The ingredients shall be accurately measured by volume and shall be well and evenly mixed together before adding required amount of water to make homogeneous paste of workable consistency. If hand mixing is allowed, it shall be done in clean and smooth hard platform. The gauged materials shall be put in the platform and mixed dry thoroughly. Water in required quantity will then be added and the whole mix will be mixed again until it is homogeneous and of uniform colour.

a.) Sand

Sand shall comply with IS: 2116. It shall consist of natural sand, crushed stone sand, crushed gravel sand or a combination of any of them. It shall be hard, durable, clean and

free from deleterious & organic matters. It shall not contain clay, silt and fine dust more than 5 % by weight. The particle size grading of sand shall be within the limits as specified in Table 6.1

Table 6.1: Grading envelope for sand for Masonry work

Sieve size (mm)	Percentage passing by weight
4.75	100
2.36	90- 100
1.18	70-100
0.6	40-100

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0.3	5-70
0.15	0-15

b.) Cement

Cement shall be ordinary Portland cement and shall comply with following requirements.

Ordinary and High Strength Portland Cement (OPC and HSPC), Portland Slag Cement (PSC), Portland Pozzolana Cement (PPC) shall be sampled according to IS: 3535 and tested according to NS: 123/IS: 4031.

Chemical and physical requirements for Ordinary Portland Cement, High Strength Portland Cement, Portland Slag Cement and Portland Pozzolana Cement shall be in accordance with NS: 49/IS: 269, IS: 8112, IS: 12269, IS: 455, IS: 1489 respectively.

The requirements on their physical characteristics shall be as given in Table 6.2

Table 6.2: Requirement on the Physical Characteristics of Cement

S.N.	Physical Characteristics	OPC/ PSC	HSPC	Test Procedure
i)	Fineness, m^2/kg: (by Blaine's Air Permeability method)	225	225	
ii)	Setting Time:			NS 123
	(a)Minimum Initial Setting Time(minutes)	45	45	
	(b)Maximum Final Setting Time(minutes)	600	600	
iii)	Soundness by Lechatelier Method, mm, maximum	10	10	NS: 123
iv)	Compressive Strength:			
	Minimum average Compressive Strength of three mortar cube (N/mm^2)			
	(a) 3 days	16	27	
	(b) 7 days	22	37	
	(c) 28 days	33	53	

Mortar shall comply with IS 2250-1981; Code of Practice for preparation and use of masonry mortar. The mortar used in work shall have the strength not less than 5 N/mm2 or 7.5 N/mm2 at 28 days as specified.

However, if provided in the Contract, cement and sand may also be mixed in specified proportions. Cement shall be proportioned only by weight, by taking its unit weight as 1440 kg/m^3 and sand shall be proportioned by volume after making due allowance for bulking.

The mixing shall be done in a mechanical mixer unless hand-mixing is permitted by the Engineer. If hand-mixing is allowed, the operation shall be carried out on a clear watertight platform. In the required proportion cement and sand shall be first mixed dry to obtain a uniform colour. Then required quantity of water shall be added and the mortar shall be mixed to produce workable consistency. The mortar shall be mixed for at least three minutes after addition of water in the case of mechanical mixing. In the case of hand mixing, the mortal shall be hoed back and forth for about 10 minutes after addition of water in order to obtain uniform consistency.

Only that quantity of mortar shall be mixed at a time which can be used completely before it becomes unworkable. Any mortar that has become unworkable due to loss of water before elapsing the initial setting time of cement, shall be rewet to make it workable and shall be used in the works. On no account mortar shall be used after elapsing the initial setting time of cement.

(ii) Lime Surkhi Mortar

Lime Surkhi/Lime Surkhi Sand mortar shall be mixed in proportion of materials as indicated in the contract. The ingredients shall be accurately measured by volume and shall be well and evenly mixed together

before adding water to make homogeneous and workable paste. If hand mixing is allowed, it shall be done on a clean and smooth hard platform. The gauged materials shall be put on the platform and mixed dry thoroughly. Water in required quantity will then be added and the whole mix will be mixed again until it is homogeneous and uniform in colour.

a) Lime

Limes shall be sampled and tested in accordance with IS: 1514 and shall comply with all requirements specified therein.

Lime to be used for brick masonry works shall be Hydrated Calcium Lime or Quicklime and, unless otherwise specified, shall comply with the requirements given in Table 6.3.

Table 6.3: Requirements of Lime for Brick Masonry Work

S. N.	Characteristics	Hydrated lime	Quicklime
i)	Fineness		
	Residue on 0.212 mm sieve, Maximum	1%	10%
	Residue on 0.775 mm sieve, Maximum	100%	50%
ii)	Chemical requirements		
	Free lime content, Minimum	50%	60%
	Hydrated lime content, Maximum	-	5%

b) Surkhi

Ground broken brick (burnt clay), commonly known as SURKHI, is used as fine aggregate in the preparation of lime Surkhi mortar/Lime Surkhi Sand mortar where fine aggregates derived from natural sources are not available in plenty or where its cost is prohibitive. It is a good alternative to sand to be used in mortar for masonry requiring lower loads and less severe conditions of service where well-burnt bricks are available in sufficient quantity.

It shall be free from under burnt clay particles, soluble salts and adherent coating of soil or silt. The Surkhi shall be of the required grading when tested for sieve analysis according to IS: 2386 (Part 1) - 1963.

Surkhi when tested in accordance with the method of test indicated, shall also conform to the requirements given in Table 6.4.

Table 6.4: Requirements of Surkhi for Brick Masonry Work

Characteristics	Requirements	Reference to Method of Test
Specific gravity	2.4-2.7	IS : 2386 (Part 3)-1963
Clay and silt, percent, Max	5	IS : 2386 (Part 2)-1963
Materials finer than 0.075 mm IS sieve, percent, Max	15	IS : 2386 (Part 1)-1963
Water soluble matter, percent, Max	1	Appendix B of IS : 3068-1986

(iii) Mud Mortar

Mud mortar shall be prepared from the selected clay of required quality after mixing water to make homogeneous and workable paste. The hand mixing shall be done in clean and smooth hard platform. Thickness of mud mortar should not be more than 20 mm in case of brick masonry work.

a) Clay

The Clay for preparation of mud mortar shall be free from gravel coarse sand (particle size greater than 2 mm) lime and kankar particles vegetable matter, etc. The clay shall conform to the following mechanical composition when Grain size analysis is done in accordance with the method given in IS 2720 (Part 4)-1986:

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Clay 18-22 percent by weight

Silt 40-45 per cent by weight

Sand 30-40 percent by weight

The total content of clay and silt shall be preferably not less than 60 percent by weight. The plasticity index when determined in accordance with IS 2720 (Part 5): 1970 shall range between 12 and 15.

b) Water

Water shall be clean and free from harmful matter and shall comply with the requirements of IS 456. Brackish water containing more than 1000 ppm chloride ion or 2000 ppm sulphate ion shall not be used. The Contractor shall carry out tests in compliance with IS 456 to establish compliance with Specifications.

603 SOAKING OF BRICKS

Bricks shall be soaked in water for a minimum period of one hour before use. When bricks are soaked they shall be removed from the tank sufficiently in advance so that at the time of laying they are skin dry. Such soaked bricks shall be stacked on a clean place where they are not spoilt by dirt, earth, etc.

604 LAYING OF BRICKS

All bricks work shall be laid in English bond, even and true to line, plumb, level and all joints accurately kept. Whole bricks used on the face shall be selected ones of uniform size and true rectangular face.

Bricks shall be laid with frogs up, if any, on a full bed of mortar. When laying, bricks shall be slightly pressed so that the mortar gets into all the surface pores of bricks to ensure proper adhesion. All joints shall be properly flushed and packed with mortar so that no hollow spaces are left.

Before laying bricks in foundation, a layer of not less than 12 mm of mortar shall be spread to make the surface on which the brick work will be laid even. Immediately thereafter, the first course of bricks shall be laid.

The brick work shall be built in uniform layers. Corners and other advanced work shall be raked back. Brick work shall be done true to plumb or in specified batter. No part of it, during construction, shall rise more than one meter above the general construction level, to avoid unequal settlement and improper jointing.

Tooting may be done where future extension is contemplated but shall be used as an alternative to raking back.

605 JOINTS

The thickness of joints in case of brick masonry shall not exceed 10 mm.

606 JOINTING WITH EXISTING STRUCTURES

When fresh masonry is to be placed against existing surface of structures, the surface shall be cleaned of all loose materials, roughened and wetted as directed by the Engineer so as to affect a good bond with the new work.

607 CURING

Green work shall be protected from rain by suitable covering. Masonry work in cement mortar shall be kept constantly moist on all faces for a minimum period of seven days. The top of the masonry work shall be left flooded with water so as not to disturb or washout the green mortar.

During hot weather, all finished or partly completed work shall be covered or wetted in such a manner as to prevent rapid drying of the brick work

Alternatively, use of Chemical may be proposed by the Contractor to assist him for curing. Contractor shall submit to the Engineer full details of the Chemical he purposes to use and the manner in which he proposed to add in the mortar mix/ paint. Approval of the Engineer shall be obtained based on test of the mortar.

608 SCAFFOLDING

The scaffolding shall be sound and strong to withstand all loads likely to come upon it. The holes which provide resting space for horizontal members shall not be left in masonry under one meter in width or immediately near the skew backs of arches. The holes left in the masonry work for supporting the scaffolding shall be filled and made good.

609 CONDITIONS OF EQUIPMENT

All equipment used for mixing or transporting mortar and bricks shall be clean and free from set mortar, dirt or other injurious foreign substances.

610 TEST AND STANDARD OF ACCEPTANCE

Before laying any cement sand mortar, the Contractor shall make three sets of mortar test cubes from each source of sand to demonstrate the compliance of the mortar to the specified strength. Each set shall comprise two cubes, one to be tested at 7 days and the other to be tested at 28 days. Testing shall be in accordance with IS 2250. During construction the Contractor shall make and test mortar cubes at the rate of three for every $10m^3$ or part of it of brick work to assess the strength of the mortar subject to a minimum of 3 sample cubes for a day's work. The brick shall be tested for compressive strength and water absorption as per NS-1/2035 and shall meet the requirement of this Specification.

611 MEASUREMENT

All brick works shall be measured in cubic meters.

612 PAYMENT

The brick works shall be paid at their respective contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115 to complete the work as per these Specifications.

SECTION 700: STONE WORKS

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701 SCOPE

This Section covers the furnishing of materials and construction of different types of stone masonry works in accordance with the Drawing and this Specifications or as directed by the Engineer.

702 MATERIALS

(1) Stone

The stones to be used shall be durable and angular in shape. If boulders are used, they shall be broken into angular pieces. The stones shall be sound, hard, and free from iron bands, spots, sand holes, flaws, shakes, cracks or other defects. The stone shall not absorb water more than 5 per cent. The specific gravity of the stone shall not be less than 2.50. Except otherwise described in the contract, the length of any stone shall not exceed three times its height. The breadth of the stone on the bed shall not be less than 150 mm nor greater than 3/4 the thickness of the wall. At least 85% of the stones used in masonry, except those used for chinking as chips or spalls of stones shall have individual volumes of more than 0.01 m3. The chips or spalls used including voids in the dry stone masonry shall not be more than 20% of the stone masonry by volume. In case of mortared masonry, the total volume of mortar and spalls taken together shall not be more than 30% of the mortared masonry. Representative samples of the stones intended for use in the works shall be submitted to the Engineer for prior approval. Further representative samples shall be submitted for approval whenever there is a change in the type or strength of the rock that the Contractor intends to use in masonry work.

(2) Mortar

Mortar for masonry shall conform to Sub-clause 602 (2).

703 CONSTRUCTION

The method of construction described herein shall hold in all Clauses of this Section, wherever applicable.

(1) General

Construction shall be carried out in accordance with I.S. 1597-1992, Code of Practice for construction of stone masonry, Part 1 Rubble stone masonry or Part 2 Ashlar Masonry as appropriate. All stratified stone possessing bedding planes shall be laid with its natural bed as nearly as possible at right angles to the direction of load. In the case of arch rings, the natural bed shall be radial. Face work groins shall be built to a height not exceeding one meter in advance of the main body of the work and adjacent walling stepped down on either side. Masonry face work between the groins shall then be built to a height not exceeding 500 mm above the backing which shall then be brought up level with the completed face work. At no time shall the backing be built up higher than the face work.

Except for dry rubble walling, all joints (gaps) shall be sufficiently thick to prevent stone to stone contact and the gaps shall be completely filled with mortar. Stones shall be clean and sufficiently wetted before laying to prevent absorption of water from mortar.

Placing loose mortar on the course and pouring water upon it to fill the gaps in stones shall not be allowed. Mortar shall be fluid, mixed thoroughly and then poured in the joints. No dry or hollow space shall be left anywhere in the masonry and each stone shall have all its faces completely covered with mortar of the thickness as specified for joints.

The bed which is to receive the stone shall be cleaned, wetted and covered with a layer of fresh mortar. All stones shall be laid full in mortar both in bed and vertical joints and settled carefully in place with a wooden mallet immediately after placement and solidly embedded in mortar before it has set. Clean and wet chips and spalls shall be wedged into the mortar joints and bed whenever necessary to avoid thick joints or bed of mortar. When the foundation masonry is laid directly on rock, the bedding face of the stones of the first course shall be dressed to fit into rock snugly when pressed down in the mortar bedding over the rock. For masonry works over rock, a levelling course of M15/40 or M15/20 concrete 100mm thickness

shall be laid over rock and then stone masonry work shall be laid without foundation concrete block.

In case, any stone already set in mortar is disturbed or the joints broken, it shall be taken out without disturbing the adjoining stones and joints. Dry mortar and stones thoroughly cleaned from the joints and the stones shall be reset in fresh mortar. Sliding one stone on top of another which is freshly laid, shall not be allowed.

Shaping and dressing of stone shall be done before it is laid in the work. Dressing and hammering of the laid stones which will loosen the masonry, shall not be allowed.

Building up face wall tied with occasional through stones and filling up the middle with stones spalls and chips or dry packing shall not be allowed. Vertical joints shall be staggered. Distance between the nearer vertical joints of upper layer and lower layer in coursed rubble masonry shall not be less than half the height of the course.

Masonry in a structure between two expansion joints shall be carried up nearly at one uniform level throughout but when breaks are unavoidable the masonry shall be raked in sufficiently long steps to facilitate jointing of old and new work. The stepping of raking shall not be more than 45 degrees with the horizontal.

Masonry shall not be laid when the air temperature in the shade is less than 3°C. Newly laid masonry shall be protected from the harmful effects of weather.

(2) Concreting Capping

Where masonry structures are to receive a concrete capping. The joints to the upper surface of the masonry shall be raked out to a depth of 10 mm prior to placing of the concrete to the capping. The concrete for capping shall be as per the Drawing or as directed by Engineer and shall conform to Section 800.

(3) Pointing

Where external faces of the mortared masonry work will be backfilled or otherwise permanently covered up, the mortared joint shall be finished flush to the faces of the adjacent stonework.

Where mortared masonry faces will remain exposed, the mortar joints shall be pointed to a consistent style as shown on the Drawing. Pointing shall be carried out using mortar 1:3 by volume of cement and sand or as shown on the Drawing. The mortar shall be filled and pressed into the raked out joints before giving the required finish. The pointing, if not otherwise mentioned shall be ruled type for which it shall, while masonry work is still green, be ruled along the centre with half round tools of such width as may be specified by the engineer. The excess mortar shall then, be taken off from the edges of the lines and shall not be unnecessarily plastered over the exposed stone works. The thickness of the joints shall not be less than 3mm for Ashlar masonry.

However, the maximum thickness of joints in different works shall be as follows:

Random Rubble: 20 mm

Coursed Rubble: 15 mm

Ashlar masonry: 5 mm

704 ASHLAR

All stones shall be dressed to accurate planes on the beds and joints and they shall be fair and neatly or fine tooled on the face unless otherwise described in the contract.

705 BLOCK-IN-COURSE

Beds and joints shall be squared and dressed for a distance of at least 220 mm from the exposed face. Bond stones shall form at least one sixth of the area of the exposed face and shall extend at least 900 mm into the wall or for the full thickness of the wall if the latter is less than 900 mm. Unless described in the contract as tooled or drafted, the exposed face of all stones shall be blocked and left rough. Arises shall

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be dressed square at all beds and joints.

706 SQUARE RUBBLE-COURSED OR BROKEN COURSE

All stones shall be truly squared and dressed for a distance at least 120 mm from the face of the wall. Bond stones shall be provided at the rate of at least one to every 0.8 m^2 of exposed face and shall measure not less than 150 mm x 150 mm on the face and not less than 450 mm in length or the full thickness of the wall, whichever is the less. Vertical joints in any layer shall be broken in the next layer and the horizontal lapping of the stones shall not be less than 100 mm.

707 RANDOM RUBBLE-COURSED OR UNCOURSED

All stones shall be carefully set with a bond stone provided at the rate of at least one to every 0.9 m^2 of exposed face. Bond stones shall measure not less than 150 mm x 150 mm on the exposed face and not less than 450 mm in length or the full thickness of the wall, whichever is the less.

708 DRY RANDOM RUBBLE

Dry random rubble masonry shall be constructed generally to the requirements of coursed random rubble masonry as specified in Clause 707 but with the omission of mortar. All stones shall be carefully shaped to obtain as close a fit as possible at all beds and joints, any interstices between the stones being filled with selected stone spalls. The stones in courses shall be laid perpendicular to the batter face. The exposed tops or capings of dry rubble structures shall be formed as shown on the Drawing.

709 COMPOSITE RANDOM RUBBLE

Materials for composite random rubble shall comply with Clause 702 and construction with Clause 703. Mortar masonry shall be coursed and comply with Clause 707 and the dry stone insets with Clause 708. The dry stone insets shall be constructed when the level of the surrounding mortared masonry surround has reached the top of the dry stone inset.

710 CONCRETE BLOCKS

A. CONCRETE MESH BLOCK

Concrete mesh block which is lighter but durable than solid concrete block shall be laid in 1:4 Cement sand mortar as specified in the BoQ. The finished surface should be smooth and lightening. After the wall constructed with concrete mesh block, it should be properly cured to attain the required strength.

Mortar for masonry shall conform to Sub-clause 602 (2).

B. CONCRETE HOLLOW BLOCK

Concrete hollow blocks which are commonly used in walls, partition and foundation shall be laid in 1:4 and 1:6 cement sand mortar as required and specified in the BoQ. The size of the block should be 200mm x 200mm x 150mm unless otherwise specified. The ratio of cement sand mortar may be different if specified other way in the BoQ of contract document. The finished surface should be smooth and shining. After the wall constructed with concrete hollow block, it should be properly cured to attain the required strength.

Mortar for masonry shall conform to Sub-clause 602 (2).

C. AUTOCLAVED AERATED CONCRETE (AAC) BLOCK

Autoclaved Aerated Concrete blocks which are commonly used in residential and commercial buildings for walls, roofing, and partitions shall be laid in 1:4 and 1:6 cement sand mortar as required and specified in the BoQ. The size of the block should be 600mm x 200mm x 200mm unless otherwise specified. The ratio of cement sand mortar may be different if specified other way in the BoQ of contract document. The finished surface should be smooth and glowing. After the wall constructed with AAC block, it should be properly cured to attain the required strength.

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Mortar for masonry shall conform to Sub-clause 602 (2).

D. CONCRETE SOLID BLOCK

Concrete solid blocks which are commonly used in foundations, walls, and structures requiring high durability shall be laid in 1:4 and 1:6 cement sand mortar as required and specified in the BoQ. The size of the block should be 400mm x 200mm x 200mm unless otherwise specified. The ratio of cement sand mortar may be different if specified other way in the BoQ of contract document. The finished surface should be smooth and shining. After the wall constructed with concrete solid block, it should be properly cured to attain the required strength.

Mortar for masonry shall conform to Sub-clause 602 (2).

711 TEST AND STANDARD OF ACCEPTANCE

Before laying any mortar, the Contractor shall make three sets of mortar test cubes from each source of sand to demonstrate the compliance of the mix to the specified strength. Each set shall comprise two cubes, one to be tested at 7 days and the other to be tested at 28 days. During construction, the Contractor shall make and test mortar cubes at the rate of three cubes for every $10m^3$ of masonry to assess the strength subject to a minimum of 3 cubes samples for a day's work. Testing of cubes shall be in accordance with IS: 2250. The stones shall be tested for the water absorption as per IS: 1124 and it shall not be more than 5 percent. The stones shall also be tested for Specification specific gravity and it shall not be less than 2.5. Sand shall be tested as per Clause 610 or as directed by the Engineer. At least 3 set of tests for stone and sand shall be conducted for every source.

712 MEASUREMENT

Stone masonry shall be measured in cubic metres. The pointing shall be measured in sq. m.

713 PAYMENT

The stone masonry and the pointing shall be paid at the respective contract unit prices which shall be the full and the final compensation to the Contractor as per Clause 115.

SECTION 800 – CEMENT CONCRETE WORKS

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801 SCOPE

This Section named Cement concrete works covers the materials required, design of mixes, transport, placing, compaction and curing of concrete and mortar required for different concrete works for concrete structures. It also covers steel reinforcement for concrete.

802 DEFINITIONS

Structural concrete is any class of concrete which is used in reinforced, pre-stressed or unreinforced concrete construction which is subject to stress.

Non-structural concrete is composed of materials complying with the Specification but for which no strength requirements are specified and which is used only for filling foundations and similar purpose where it is not subjected to significant stress.

A pour refers to the operation of placing concrete into any mould, bay or formwork, etc. and also to the volume which has to be filled. Pours in vertical succession are referred to as lifts.

803 MATERIALS FOR CONCRETE

(1) General

The Contractor shall submit to the Engineer full details of all materials which he purposes to use for making concrete. No concrete shall be placed in the works until the Engineer has approved the materials of which it is composed. Approved materials shall not thereafter be altered or substituted by other materials without the consent of the Engineer.

(2) Cement

Cement shall comply with the requirements of Clause 602.

Cement shall be free flowing and free of lumps. It shall be supplied in the manufacturer's sealed unbroken bags or in bulk. Bagged cement shall be transported in vehicles provided with effective means of ensuring that it is protected from the weather.

Bulk cement shall be transported in vehicles or in containers built and equipped for the purpose.

Cement in bags shall be stored in a suitable weatherproof structure of which the interior shall be dry and well ventilated at all times. The floor shall be raised above the surrounding ground level not less than 30 cm and shall be so constructed that no moisture rises through it.

Each delivery of cement in bags shall be stacked together in one place. The bags shall be closely stacked so as to reduce air circulation with min gap of 500 mm from outside wall. If pallets are used, they shall be constructed so that bags are not damaged during handling and stacking. Stack of cement bags shall not exceed 8 bags in height. Different types of cement in bags shall be clearly distinguished by visible marking and shall be stored in separate stacks.

Cement form broken bags shall not be used in the works. Cement in bags shall be used in the order in which it is delivered.

Bulk cement shall be stored in weather proof silos which shall bear a clear indication of the type of cement contained in them. Different types of cement shall not be mixed in the same silo.

The Contractor shall provide sufficient storage capacity on site to ensure that his anticipated programme of work is not interrupted due to lack of cement.

Cement which has become hardened or lumpy or fails to comply with the Specification in any way shall be removed from the Site.

All cement for any one structure shall be from the same source as far as possible.

All cement used in the works shall be tested by the manufacturer. The manufacturer shall provide the

results of tests as given in Table 6.2 for each supply and for the last six months of his production.

Each set of tests carried out by the manufacturer on samples taken from cement which is subsequently to site shall relate to no more than one day's output of each cement plant.

The Contractor shall constitute each type of cement and required number of representative samples to be tested when instructed by the Engineer in a laboratory acceptable to him, in case of the concrete mixes do not comply with the requirements of this Specification.

Cement which is stored on site for longer than one month shall be tested in such laboratory for every 200 tons or part thereof and at monthly intervals thereafter.

The Contractor shall keep full records of all data relevant to the manufacture, delivery, testing and the cement used in the works and shall provide the Engineer with two copies thereof.

(3) Fine Aggregate

Fine aggregate shall be clean hard and durable and shall be natural sand, crushed gravel sand or crushed rock sand complying with IS 383. All the material shall be in accordance Table 8.1.

Table 8.1 Grading Requirement for fine aggregate

IS Sieve Standard Mesh	Grading Zone 1	Grading Zone 2	Grading Zone 3	Grading Zone 4
10.0 mm	100	100	100	100
4.75 mm	90 - 100	90 – 100	90 - 100	95 - 100
2.36 mm	60 - 95	75 – 100	85 - 100	95 - 100
1.18 mm	30 - 70	55 – 90	75 - 100	90 - 100
600 μm	15 - 35	35 – 60	60 - 80	80 - 100
300 μm	5 - 20	8 – 30	12 - 40	15 - 50
150 μm	0 - 10	0 – 10	0 - 10	0 – 15

In order to achieve an acceptable grading, it may be necessary to blend materials from more than one source. The deviation from the initial fineness modulus shall be no more than ± 0.30 for ordinary concrete and ± 0.20 for high quality concrete.

However, in respect of the presence of deleterious materials the fine aggregate shall not contain iron pyrites, iron oxides, mica, shale, coal or other laminar soft or porous materials or organic matter unless the Contractor can show by comparative tests on finished concrete as set out in Table 8.4 and as per the direction of the Engineer, that presence of such materials does not affect the properties of the concrete.

(4) Coarse Aggregate

Coarse aggregate shall be clean, clear, dense, hard, strong and durable crushed rock, crushed gravel or natural gravel. As far as possible, flaky, coriaceous and elongated pieces should be avoided. Coarse aggregate shall be supplied in the nominal size called for in the contract and shall be of the grading as specified in Table 8.2.

Table 8.2 Grading Requirement for Coarse Aggregate

S.N	IS sieve Designation	Percentage Passing for Single Sized Aggregate of nominal Size						Percentage Passing for Graded Aggregate of Nominal Size			
		63 mm	40 mm	20 mm	16 mm	12.5 mm	10 mm	40 mm	20 mm	16 mm	12.5 mm
i)	80 mm	100						100			
ii)	63 mm	85-100	100								
iii)	40 mm	0-30	85-100	100				90-100	100		
iv)	20 mm	0-5	0-20	85-100	100			30-70	90-100	100	100
v)	16 mm				85-100	100				90-100	
vi)	12.5 mm					85-100	100				90-100
vii)	10 mm	0-5	0-5	0-20	0-30	0-45	85-100	10-35	25-35	30-70	40-85
viii)	4.75 mm			0-5	0-5	0-10		0-5	0-10	0-10	0-10
ix)	2.36 mm										

Other properties shall be set out below:

Flakiness Index: When tested in accordance with IS 2386 Part 1, the Flakiness Index of the coarse aggregate shall be as set out hereunder:

For ordinary concrete: not more than 25

For high quality concrete: not more than 15

If the Flakiness Index of the coarse aggregate varies by more than five units from the average value of the aggregate used in the approved trial mix, then a new set of trial mixes shall be carried out if the workability of the mixes has been adversely affected by such variation.

Water Absorption: the aggregate shall not have a water absorption of more than 2 per cent when tested as set out in IS: 2386 Part 3.

Los Angeles Abrasion (LAA): The aggregate shall have LAA not more than 50% for ordinary concrete, and not more than 30% for high quality concrete (wearing surface), when tested in accordance with IS: 2386 Part 4.

Aggregate Crushing Value (ACV): The aggregate shall have ACV not more than 30% for wearing surfaces such as road and pavement structure and not more than 45% for other structure when tested in accordance with IS: 2386 Part 4.

Alkali Aggregate Reactivity (AAR): Coarse aggregates having positive alkali-silica reaction shall not be used for concreting. The aggregate shall comply with IS 456 when tested in accordance with IS: 2386 Part 7.

Testing Aggregate

(a) Acceptance Testing

The Contractor shall deliver to the Engineer samples containing not less than 50 kg of any aggregate which he proposed to use in the works and shall supply such further samples as the Engineer may require. Each sample shall be clearly labeled to show its origin and shall be accompanied by all information called for in IS: 2386 Part 1 to 8.

Tests to determine compliance of the aggregates with the requirements of sub-clause 803 (3) and (4) shall

be carried out by the Contractor in a laboratory acceptable to the Engineer. If the tested materials fail to comply with the Specification, further tests shall be made in the presence of the Contractor and the Engineer. Acceptance of the material shall be based on the results of such tests.

All the materials shall be accepted if the results of not less than three consecutive sets of test executed in accordance with IS 2386 (Part 1-8) show compliance with the Sub- clause 803 (3) and (4).

Compliance Testing/Process Control Testing

The Contractor shall carry out routine testing of aggregate for compliance with the Specification during the period that concrete is being produced for the works. Frequency test shall be as follows:

		Test procedure	Frequency
Fine aggregate and	Grading Silt,Clay Contents and Organic Impurities	IS: 2386 Part 1 IS: 2386 Part2	1 set (3 nos) test for each 10 to 50 cum and additional test for each 50 cum of concrete
Coarse Aggregate	GradingSilt, Clay Contents and Organic Impurities	IS: 2386 Part 1 IS: 2386 Part2	1 set (3 nos) test for each 25 to 125 cum and additional test for each 125 cum

If the aggregate from any source is variable, the frequency of testing shall be increased as instructed by the Engineer. Chloride Content: As frequently as may be required to ensure that the proportion of chlorides in the aggregates does not exceed the limit stated in the Specification.

Sulphate Content and Alkali Aggregate Reactivity: As frequently as may be required according to the variability of sulphate content and alkali reactivity assessed from the laboratory test carried out during the concrete mix design.

Delivery and Storage of Aggregate

Aggregate shall be delivered to site in clean and suitable vehicles. Different type or sizes of aggregate shall not be delivered in one vehicle.

Each type or size of aggregate shall be stored in a separate bin or compartment having a base such that the contamination of aggregate is prevented. Dividing walls between bins shall be substantial and continuous so that no mixing of types or sizes occurs.

The storage of aggregate shall be arranged in such a way that drying out in hot weather is prevented in order to avoid fluctuations in water content. Storage of fine aggregates shall be arranged in such way that they can drain sufficiently before use in order to prevent fluctuations in water content of the concrete.

(5) Water

Water used in mixing and curing of concrete shall be subject to approval, and shall be reasonably clean and free of oil, salt, acid, alkali, sugar, vegetable or other substances injurious to the finished project. In no case shall the water contain an amount of impurities which will cause a change in the time of

initial or final set of the cement of more than 30 minutes, nor a reduction in the compressive strength of mortar of more than 10 per cent at any time of testing, when compared to the results obtained with distilled water.

Water for mixing, washing aggregates, curing and rinsing shall not contain:

Organic <200 mg/lit;

Inorganic <3000 mg/lit

Sulphates as SO3; <400 mg/lit

Chlorides	<2000 mg/lit	for plain concrete
	<500 mg/lit	for reinforced concrete
Suspended matter	<2000 mg/lit;	
pH	≥ 6.	

Furthermore, the chloride content in mixing water must be such that in no case, the total amount of chlorides in water, cement, aggregates and additives of the fresh concrete, shall exceed 0.3 per cent of the weight of cement.

The Contractor shall deliver to the Engineer, without charge, samples of the water proposed for use in the Works, for the Engineer to carry out such tests as he may require to confirm its suitability. Samples will be delivered sufficiently in advance of the Works for completion of the tests before the water is required for use, and at such other times during the course of the Contract as the Engineer may direct. If required by the Engineer, the Contractor shall, without extra charge, treat the water taken from any other source to such a degree as may be necessary in order to render it suitable for mixing and mortar.

(6) Admixture

a) General

The use of admixtures in concrete may be required under the contract to promote special properties in the finished concrete or may be proposed by the Contractor to assist him in compliance with the Specification.

In all cases the Contractor shall submit to the Engineer full details of the admixture he proposes to use and the manner in which he proposes to add it in the mix. The information provided shall include:

I. The typical dosage, the method of dosing, and the detrimental effects of an excess or deficiency in the dosage.

II. The chemical names of the main active ingredients in the admixture.

III. Whether or not the admixture contains chlorides, and if so the chloride ion content expressed as a percentage by weight of admixture.

IV. Whether the admixture leads to the entrainment of air when used at the manufacturer's recommended dosage, and if so the extent to which it does so.

V. Details of previous uses of the admixture in Nepal.

Admixture/additives conforming to IS 9103 may be used subject to approval of the Engineer. However, admixture/ additives generating hydrogen or nitrogen and containing chlorides, nitrates, sulphides, sulphates or any other material likely to adversely affect the steel or concrete shall not be permitted.

Compatibility of the admixtures with the cement and any other pozzolan or hydraulic addition shall be ensured by for avoiding the following problems.

I. Requirement of large dosage of superplasticizer for achieving the desired workability.

II. Excessive retardation of setting

III. Excessive entrainment of large bubbles

IV. Unusually rapid stiffening of concrete

V. Rapid loss of slump

VI. Excessive segregation and bleeding

(7) Curing Material

Curing of Concrete may be done by using water, steam and membrane forming compounds. Approved membrane forming curing compound consisting of waxes, resins, chlorinated rubbers etc may be used, which shall be applied to all exposed surface of the concrete as soon as possible after the concrete has

set. Impermeable membrane such as sheet materials conforming to ASTM C 171 or polythene sheeting covering closely the concrete surface may also be used to provide effective barrier against evaporation.

804 DESIGN OF CONCRETE MIXES

(1) Classes and Grades of Concrete

The concrete used in the Works shall be of the grades or classes shown on the Drawings or indicated in the Bill of Quantities or instructed by the Engineer. The characteristics of the mixes of concrete to be used in the Works shall be as given in Table 8.3 unless otherwise approved by the Engineer.

(2) Maximum Sizes of Aggregate to be used

Unless shown on the Drawings or given in the Bill of Quantities, the maximum size of coarse aggregates in concrete for any part of the Works shall be the largest of the sizes given in Table 8.3. The Contractor shall obtain the approval of the Engineer for the maximum size of aggregates in each section of the Works.

(3) Compressive Strength Compliance

The compressive strength of the concrete shall be based on the compression testing of 150 mm concrete cubes, made and tested in accordance with IS-516, on the testing equipment installed by the Contractor in the Site Laboratory under the supervision of the Engineer.

The compressive strength of the concrete is specified by the specified compressive strength in Table 8.3 for each grade of concrete. The concrete in the Works shall be considered to comply with the compressive strength requirements specified in Table 8.3 if 28-day cube strengths shown in Table 8.4 are equal or exceeded.

Table 8.3: Classes of Concrete

Concrete Classes	**M50**	**M40**	**M35**	**M25**	**M 20**			**M 15**		**M 10**
Grades	M50/20	M 40/20	M35/20	M 25/20	M 20/40	M 20/20	M 20/10	M 15/40	M 15/20	M 10/40
Maximum Aggregate Size (mm)	20	20	20	20	40	20	10	40	20	40
Specified Compressive Strength (N/sq.mm.)	50	40	35	25	20	20	20	15	15	10
Minimum Cement Content (kg/cu.m.)	400	375	375	375	330	330	330	290	290	220
Maximum Cement Content (kg/cu.m.)	450	425	425	425	400	400	400	400	400	400
Maximum Water to Cement Ratio	0.40	0.5	0.5	0.5	0.50	0.50	0.50	0.55	0.60	0.60

The tentative use of the above classes of concrete shall be as follows:

Class	**Tentative Use of Concrete**
M 50	- Precast Piles, Heavy Diversion Structures, Wearing coat - High-velocity dam spillway glacis and buckets exposed to severe erosion/cavitation. - Penstock anchor blocks in high-thrust zones. - Spiral case embedding for high-head hydropower turbines. - Long-span prestressed concrete aqueduct girders.

M 45	- High-velocity chute spillways, sluice ways, and energy dissipators (velocity > 25 m/s). - High-pressure tunnel linings and surge shaft structural rings. - Precast high-capacity aqueduct shell units and deep bridge piers.
M 40	- Precast load-bearing piles and heavy diversion structures. - Bridge wearing coats and abrasion-resistant operational decks.
M 35	- Weir bodies, surge shafts, stilling basins, and under-sluice structures. - Bridge piers, abutments, high retaining walls, flood walls, and divide walls. - Standard reinforced structural components like girders, beams, and operating platforms.
M 30	- Water retaining structures (mandated minimum by *IS 3370* for liquid-exposed RCC) such as overhead tanks, sump wells, and reservoir walls. - Headworks intake structures and desanding/sedimentation basin walls. - Reinforced concrete lined canals subjected to medium flow velocities (4 to 8 m/s). • Gate supporting frames and general structural slabs.
M 25	- Minor precast units, structural canal lining, and surface wearing courses. - General reinforced concrete works under mild environmental exposures.
M 20	- General reinforced concrete at important and/or thin parts and structural sections.
M 15	- Reinforced concrete at less critical and/or thick structural sections. - Plain concrete (PCC) at less important and/or thin structural sections. - Blinding concrete beddings and plum concrete works (e.g., gravity retaining walls).
M 10	- Plain concrete (PCC) at less important and/or thick sections. - Mass concrete foundations and gravity structures. - Levelling courses, mud mats, and lean concrete underpinnings.

The standard deviation (st.) in Table 8.4 shall be determined from cube results of at least 30 separate batches of concrete for each concrete grade produced on the Site from similar materials by the same plant under similar supervision. When 30 cube results are not available and for the initial mix designs the value of the standard deviation shall be taken as Table 8.5.

The concrete represented by a group of four consecutive test cubes shall include the batches from which samples were taken to make the first and last cubes in the group of four, together with all the intervening batches. If only one cube result fails to meet the minimum individual cube strength given in Table 8.4, then the result shall be considered to represent only the particular batch of concrete from which that cube was taken, provided that the average strength of the group of four results in which the low cube occurs satisfies the second requirement of Table 8.4. The action to be taken in respect of the concrete represented by test cubes which fail to meet the compliance values given in Table 8.4 shall be determined by the Engineer which may range from qualified acceptance in less severe cases, to rejection and removal.

Table 8.4: Cube Strength Compliance Values

Concrete Grade	Minimum Individual Cube Result (N/sq.mm.)	Mean of any Four Consecutive Cube Results (N/sq.mm.)
M 40/20	36	40 + 0.825 st or f_{ck} + 4
M25/20	21.1	25+0.825 st or f_{ck} + 4
M 20/40	17	20 + 0.825 st. or f_{ck} + 4
M 20/20	17	20 + 0.825 st. or f_{ck} + 4
M 20/10	17	20 + 0.825st. or f_{ck} + 4
M 15/40	12.8	15 + 0.825 st. or f_{ck} + 3
M 15/20	12.8	15 + 0.825 st. or f_{ck} + 3
M 10/40	8.5	10 + 0.825 st. or f_{ck} + 3

Table 8.5: Standard Deviation for Mix design

Concrete Grade	Standard Deviation (N/sq.mm)
40/20	5
25/20	4
20/40	4
20/20	4
20/10	4
15/40	4
15/20	3.5
10/40	3.5

(4) Water Cement Ratio

The maximum water cement ratios specified in Table 8.3 shall be the ratios by weight of free water to cement in the mix based on the aggregates being in a saturated surface dry condition. Throughout concrete production the actual water cement ratio shall be strictly monitored and the batch quantities of aggregates and water regularly adjusted to maintain the design water cement ratio.

(5) Water and Slump Tests

A check on the moisture content of the aggregate shall be made before concreting begins, for the purpose of assessing the amount of free water to be added at the mixer.

The Contractor shall provide himself with a chart, a copy of which shall be given to the Engineer for approval, relating moisture content in aggregate and water to be added at the mixer for the class of concrete in use. The amount of water introduced into the mix shall be strictly controlled and shall be the minimum amount consistent with complete compaction.

The device for measuring water shall show accurately the quantity, and be so designed that the water supply will be automatically cut off while water is being discharged into the mix. Frequent slump tests shall be carried out in accordance with IS:1199 and samples of concrete taken immediately before placing to determine the consistency of the concrete. The slumps of the trial mixes shall be recorded for identification

purposes and for subsequent use as a rough routine check on quality.

(6) Workability

Concrete shall be of such consistency that it can be readily worked into the corners and angles of the formwork and around reinforcement without segregation of the materials or bleeding of free water at the free surface or against formwork. On striking the formwork the concrete shall present a face which is uniform, free from honeycombing, surface crazing, or excessive dusting, and which shall not, in the opinion of the Engineer, be inferior to the specified standards. Concrete to be placed underwater shall have high workability such that the specified strength is achieved without compaction.

Concrete workability shall be as low as practical for the placement and workability and shall be within the limits given in Table 8.6 unless otherwise approved by the Engineer.

Table 8.6: Range of Slump Values

Type of Concrete	Slump (mm)
Precast Concrete	10 to 50
Mass Concrete and Plain Concrete	25 to 75
Reinforced Concrete	50 to 100
Underwater Concrete	100 to 200

(7) Design of Proposed Mixes

Mix Design

Concrete mixes shall comply with the following requirements:

Sampling and testing on concrete shall be carried out in accordance with the standard methods given in the Table 8.7:

Table 8.7 Tests Procedures Applicable to Concrete

SN	Tests	Test Procedure
	Determination of:	
(i)	Air contents of fresh concrete	IS: 1199
(ii)	Density of hardened concrete	IS: 516
(iii)	Compressive strength of concrete cubes	IS: 516
(iv)	Tensile splitting strength	IS: 5816
(v)	Flexural strength	IS: 516
(vi)	Compressive strength of concrete cores	IS: 516
(vii)	Water absorption	
(viii)	Mixing and sampling fresh concrete in laboratory	IS: 516
(ix)	Normal curing of test specimens	IS: 516
(x)	Accelerated curing of test specimens	IS: 9013
(xi)	Marking test cubes from fresh concrete	IS: 516

I. Non-destructive tests shall be carried out in accordance with the standard method and recommendations given in Table 8.8 as and when required.

Table 8.8: Non-destructive Tests Applicable to Concrete

S.NO	Test	References to Test Procedures
(i)	ULTRASONIC PULSE VELOCITY (UPV))	IS: 13311 part-1
(ii)	Rebound hammer	IS: 13311 part-2
(iii)	Pull out test [method of testing bond in reinforcement concrete]	IS: 2720 part - 1
(iv)	RADIOGRAPHIC METHODS	BS: 1881 -205
(v)	BACKSCATTER RADIOMETRY (BSR) (Nuclear surface moisture density gauge)	ASTM C 1040
(vi)	IMPACT-ECHO	ASTM C 1383
(vii)	COVER METER and Bar locator	BS: 1881 204
(viii)	Core test	IS: 516
(ix)	Corrosion assessment/ Half-cell potential	ASTM C 876-9

II. The test specimens shall be cured at a temperature of 27oC ± 2oC

III. Water used for concrete shall comply with all the requirement given in Sub Clause 803(5). Water to be used in concrete shall be tested as specified in IS: 3025

IV. The total chloride content, expressed as chloride ion, arising from all ingredients in a mix including cement, water and admixtures shall not exceed 0.3 percent, expressed as a percentage of the weight of cement in the mix

V. The total sulphate content expressed as SO3 of all the ingredients in a mix including cement water and admixtures shall not exceed 0.4 percent by weight of the aggregate or 4.0 percent of the weight of the cement in the mix, whichever is the lesser

The contractor shall design all the concrete mixes called for in the Drawing using the ingredients which have been approved by the Engineer in accordance with Clause 803 and in compliance with the following requirements:

a) The aggregate portion shall be well graded from the nominal maximum size of stone down to the 150-micron size.

b) The cement content shall be such to achieve the strength called for in Table 8.3 but in any case, not less than the minimum necessary as shown in Table.

c) The workability shall be consistent with ease of placing and proper compaction having regard to the presence of reinforcement and other obstructions.

d) The water/cement ratio shall be the minimum consistent with adequate workability but in any case not greater than 0.5 for classes of concrete higher than M20 taking due account of any water contained in the aggregates. The Contractor shall take into account that this requirement may in certain cases require the inclusion of a workability agent in the mix.

e) For each class of concrete Contractor shall conduct laboratory trial as mentioned in 804(9) based on the results of these trials the contractor shall submit full details of his proposal including the result of test to the Engineer for approval. However, Engineer's approval shall not relieve the contractor from his responsibilities for compliance with these specifications.

f) The cement content shall not be more than 450 kg/ m^3 unless special consideration has been given

in design to cover the risk of cracking due to drying and shrinkage in thin sections or to early thermal cracking and to the increased risk of damage due to alkali silica reactions.

(8) Prescribed Mixes

Prescribed mixes shall have the proportion mentioned below

Classes of concrete	Type of uses	Characteristic Strength fck (N/mm^2)	Concrete mix	Mix proportion in case of Prescribed mix
M 10/75	Ordinary	10	Prescribed	1:3:6
M 10/40	Ordinary	10		1:3:6
M 15/20	Ordinary	15		1:2:4
M 15/40	Ordinary	15		1:2:4

Concrete mix shall be proportioned by volume. The Engineer may instruct to slight adjustment in the proportioning to allow for variations in the specific gravity and grading of aggregates. Such variation shall not be deemed to vary the price of the concrete. The Engineer shall require the contractor to make trial mixes and test work cubes to satisfy himself that the prescribed mix will give expected strengths. No concrete shall be placed in the works until the relevant mix has been approved by the Engineer and no variation shall be made in the mix after approval without the

Engineer's consent, who may require further tests to be made.

(9) Laboratory Trial Mixes

For each mix of concrete, the Contractor shall prepare three number of concrete batches with the proportion as per designed or prescribed mix as specified in the contract. The Following test shall be carried out for each sample of each batch.

- Slump Test
- Compressive strength Test of each concrete cube. [six test cubes from each batch shall be prepared and 3 cubes shall be tested for 7 days and 3 for 28 days]
- Density Test (of Concrete cubes)

Modified compositions, the quantities of other constituents being unchanged:

Water	:	+10%	1 batch
Water	:	-10%	1 batch
Cement	:	+15%	1 batch
Cement	:	-15%	1 batch

Samples shall be taken from each batch and the following action taken, all in accordance with IS: 516.

A "result" being the average strength of the three cubes from one batch, the average of the three results from tests at 28 days for the nominal composition shall not be less than the Minimal Target Strength shown in Table 8.9.

One result from the modified compositions shall not be less than the nominal strength as shown on Table 8.9.

Table 8.9: Concrete Classes and Strength

Classe of Concrete	Consistence	Type of uses	Characteristic Strength fck (N/mm^2)	Maximum Nominal Size of Aggregate mm	Trial mixes Minimal Target Strength fck=fck + 1.65*s (N/mm^2)	Early works test cubes		Concrete mix
						Any one result (N/mm^2)	Average of 3 consecutive results (N/mm^2)	
M 10/75	S	Ordinary	10	75	16	7	14	Designed / Prescribed Designed
M 10/40	S	Ordinary	10	40	16	7	14	
M 15/20	S	Ordinary	15	20	21	12	19	
M 15/40	S	Ordinary	15	40	21	12	19	
M 20/20	S	Ordinary	20	20	27	16	24	
M 20/40	S	Ordinary	20	40	27	16	24	
M 25/20	S	Ordinary	25	20	32	21	29	
M 25/40	S	Ordinary	25	40	32	21	29	
M 30/40	P	High Quality	30	40	38	26	34	
M 30/20	P	High Quality	30	20	38	26	34	
M 30/12	P	High Quality	30	12	38	26	34	
M 35/40	P	High Quality	35	40	43	31	39	
M 35/20	P	High Quality	35	20	43	31	39	
M 40/20	P	High Quality	40	20	48	36	44	
M 45/20	P	High Quality	45	20	53	41	49	Designed
M 50/20	P	High Quality	50	20	58	46	54	
SM 30/40	VP	Underwater	30	40	38	26	34	
SM 30/20	VP	Underwater	30	20	38	26	34	
SM 30/20	F	Bored Piles	30	20	38	26	34	
SM 40/20	S	Precast Piles	40	20	48	36	44	
SM 45/20	S	Post-tensioned Girders	45	20	53	41	49	

(10) Site Trials

At least six weeks before commencing placement of concrete in the permanent works, site trials shall be prepared for each class of concrete specified.

For each mix of concrete for which the Contractor has proposed a design and successfully tested in Laboratory, he shall prepare three separate batches specified hereunder using the materials which have been approved for use in the works and the

mixing plant which he propose to use for the works. The volume of each batch shall be the capacity of the concrete mixer proposed for full production.

Samples shall be taken from each batch and the action taken similar to the above Sub- clause 804 (7) (a) to (e)

The average of the three results of tests at 28 days shall not be less than the Minimal Target Strength shown in Table 8.9.

The Contractor shall also carry out tests to determine the drying shrinkage of the concrete unless otherwise

directed by the Engineer.

Based on the results of the tests on the Laboratory trial and site trial mixes, the Contractor shall submit full details of his proposals for mix design to the Engineer, including the type and source of each ingredient, and the results of the tests on the trial mixes.

If the Engineer does not agree to a proposed concrete mix for any reason, the Contractor shall amend his proposals and carry out further trial mixes. No mix shall be used in the works without the written consent of the Engineer.

(11) Quality control of Concrete Production

(a) Sampling

For each class of concrete in production at each plant for use in the works, samples of concrete shall be taken at the point of mixing or of deposition as instructed by the Engineer, all in accordance with the sampling procedures described in IS: 516 and with the further requirements set out below.

Six 150 mm cubes (1 Set) as appropriate shall be made from each sample and shall be cured and tested in accordance with IS: 516 three at seven days and the other three at 28 days. Where information samples are required, such as for post tensioning operations, three additional cubes shall be made.

The minimum frequency of sampling of concrete of each grade shall be as following:

For 1-5 m^3 quantity of work at one place	- 1 set of sample
For greater than 5-15 m^3 quantity of Work	- 2 set. of sample
For greater than15-30 m^3 quantity of work	- 3 set. of sample
For greater than 30-50 m^3 quantity of work	- 4 set. of sample
For more than 50 m^3 quantity of work	4 set .of sample plus one additional for each 50 m^3 or part thereof.

At least one set of sample shall be taken from each shifts of work.

Until compliance with the Specification has been established the frequency of sampling shall be three times that stated above and not less than 3 samples/day for each class of concrete in production at each plant or such lower frequency as may be instructed by the Engineer.

(b) Testing

I. The slump of the concrete shall be determined for each batch from which samples are taken and in addition for other batches at the point of production and deposition or at the frequency instructed by the Engineer.

   The slump of concrete in any batch shall not differ from the value established by the trial mixes by more than 25 mm or one third of the value whichever is the less.

II. The air content of air entrained concrete in any batch shall be within 1.5 times of the required value and the average value of four consecutive measurements shall be within the required value expressed as a percentage of the volume of freshly mixed concrete while tested according to IS: 1199.

III. Failure to comply with requirements:

If any one result in a group of three consecutive results is less than f_{ck} -4 (N/mm2), but the other results of group satisfy the strength requirement, then only the batch from which the failed result was obtained shall be deemed not to comply with the Specification.

If the average strength of the group is less than the strength requirement then all the batches between those represented by the first and the last result shall be deemed not to comply with the Specification, and the Contractor shall immediately adjust the production procedure or the mix design subject to the agreement of the Engineer to restore compliance with the Specification. If

Adjustment of the mix design is agreed, the Contractor shall again be required to comply with Sub-clauses 804 (9) and 804 (10).

The Contractor shall take necessary action to remedy concrete which does not comply with this Specification. Such action may include but not necessarily confined to the following:

Increasing the frequency of sampling until control is again established.

Carrying out non-destructive testing such as ultrasonic measurement, load tests or other appropriate methods.

Cutting test scores from the concrete and testing in accordance with IS: 1199.

Carrying out strengthening or other remedial work to the concrete where possible or appropriate.

Removing the concrete.

805 MIXING CONCRETE

(1) Proportioning

Concrete mixes shall be proportioned according to the Design mix or prescribed mix as specified. All mixing operations shall be supervised by experienced supervisor. Cement and aggregate shall be batched by weight or by volume as specified in the contract. Water may be measured by weight or volume. The quantity of cement, each size of aggregate and water as indicated by the mechanism employed shall be within a tolerance of plus or minus three percent of the respective weight/ volume per batch agreed by the Engineer. The water to be added to the mix shall be reduced by the amount of free water contained in the coarse and fine aggregates. This amount shall be determined by the Contractor by a method agreed by the Engineer.

(2) Machine Mixing

Concrete for the works shall be batched and mixed in one or more plants or concrete mixer unless the Engineer agrees to some other arrangement. If concrete mixers are used, there shall be sufficient number of mixtures including stand by mixers.

Batching and mixing plants shall be complying with the requirements of IS: 1791 and

capable of producing a uniform distribution of the ingredients throughout the mass. Truck mixers shall comply with the requirements of IS: 4925 and shall only be used with the prior approval of the Engineer. If the plant proposed by the Contractor does not fall within the scope of IS: 1791 it shall have been tested in accordance with IS: 4634 and shall have a mixing performance within the limits of IS: 1791.

All mixing operations shall be under the control of an experienced supervisor

The aggregate storage bins shall be provided with drainage facilities arranged so that the drainage water is not discharged to the weigh hoppers. Each bin shall be drawn at least once per week and any accumulations of mud or silt shall be removed

If bulk cement is used, the scale and weight hopper for cement shall be distinct from the scale and weight hopper for aggregates.

Cement and aggregates shall be batched by weight. Water may be measured by weight or volume.

The weighing and water dispensing mechanisms shall be maintained in good order

The nominal drum or pan capacity of the mixer shall not be exceeded. The turning speed and the mixing time shall be as recommended by the manufacturer, but in addition, when water is the last ingredient to be added, mixing shall continue for at least one minute after all the water has been added to the drum or the

pan.

The blades of pan mixers shall be maintained within the tolerances specified by the manufacturer of the mixer and the blades shall be replaced when it is no longer possible to maintain the tolerances by adjustment.

Mixers which have been out of use for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed. Mixers shall be cleaned out before changing to another type of cement.

(3) Hand Mixing

Concrete for structural purposes generally shall not be mixed by hand. However, for small volumes of works and where non-structural concrete is required, hand mixing may be carried out subject to approved of the Engineer.

For making hand mixing concrete, cement, sand and aggregate shall be batched separately by volume or by weight as applicable. Then cement and sand shall be mixed dry to uniform colour. The aggregate shall be stacked in a proper shape upon which cement sand mix shall be spread and whole mix shall be mixed to uniform consistency.

For hand mixed concrete the specified quantities of cement shall be increased by 10

% and not more than 0.25 cubic meter shall be mixed at one time. During windy weather precautions shall be taken to prevent cement from being blown away in the process of gauging and mixing.

806 TRANSPORTATION OF CONCRETE

The concrete shall be discharged from the mixer and transported to the works by means which shall prevent adulteration, segregation or loss of ingredients, and shall ensure that the concrete is of the required workability at the point and time of placing. The loss of slump between discharge from the mixer and placing shall be within the tolerances specified in

Sub-clause 804 (11) (b) (i).

The capacity of the means of transport shall not be less than the full volume of a batch.

The time elapsing between mixing transporting placing and compacting altogether of a batch of concrete shall not be longer than the initial setting time of the concrete. If the placing of any batch of concrete is delayed beyond this period, the concrete shall not be placed in the works.

807 PLACING OF CONCRETE

(1) Consent for Placing

Concrete shall not be placed until the Engineer’s consent has been given in writing.

The Contractor shall give the Engineer at least two full working day notice of his intention to place concrete.

If concrete placing is not commenced within 24 hours of the Engineer’s consent the Contractor shall again request consent as specified above.

(2) Preparation of Surface to Receive Concrete

Excavated surfaces on which concrete is to be deposited shall be prepared as set out in Section 300.

Existing concrete surfaces shall be prepared as set out in Clause 812. Before deposition of further concrete, they shall be clean, hard and sound and shall be wet but without any free standing water.

Any flow of water into an excavation shall be diverted through proper side drains to a sump or be removed by other suitable which will prevent washing away the freshly deposited concrete or any of its constituents. Any under drain constructed for this purpose shall be completely grouted up when they are no longer required by a method agreed by the Engineer.

Unless otherwise instructed by the Engineer surfaces against which concrete is to be placed shall receive prior coating of cement slurry or mortar mixed in the proportions similar to those of the fines proportions similar to those of the fines portion in the concrete to be placed. The mortar shall be kept ahead of the concrete. The mortar shall be placed into all parts of the excavated surface and shall not be less than 5 mm thick.

If any fissures have been cleaned out they shall be filled with mortar or with concrete as instructed by the Engineer.

The amount of mortar placed at one time shall be limited so that it does not dry out or set before being covered with concrete.

(3) Placing Procedures

The Concrete shall be deposited as nearly as possible in its final position. It shall be placed so as to avoid segregation of the concrete and displacement of the reinforcement, other embedded items or form work. It shall be brought up in layers approximately parallel to the construction joint planes and not exceeding 300 mm in compacted thickness unless otherwise permitted or directed by the Engineer, but the layers shall not be thinner than four times the maximum nominal size of aggregate.

When placing on a nearly horizontal surface, placing shall start at the lower end of the surface to avoid decompaction of concrete.

Layers shall not be placed so that they form feather edges nor shall they be placed on a previous layer which has taken its initial set. In order to comply with this requirement, another layer may be started before initial set of the preceding layer.

All the concrete in a single bay or pour shall be placed as a continuous operation. It shall be carefully worked round all obstructions, irregularities in the foundations and the like so that all parts are completely full of compacted concrete with no segregation or honey combing. It shall also be carefully worked round and between water stops, reinforcement, embedded steelwork and similar items which protrude above the surface of the completed pour.

All work shall be completed on each batch of concrete before its initial set commences and thereafter the concrete shall not be disturbed before it has set hard. No concrete that has partially hardened during transit shall be used in the works and the transport of concrete from the mixer to the point of placing shall be such that this requirement can be complied with.

Concrete shall not be placed during rain which is sufficiently heavy or prolonged to wash mortar from coarse aggregate on the exposed faces of fresh concrete. Means shall be provided to remove any water accumulating on the surface of the placed concrete. Concrete shall not be deposited into such accumulations of water.

In dry weather, covers shall be provided for all fresh concrete surfaces which are not being worked on. Water shall not be added to concrete for any reason.

When concrete is discharged from the place above its final deposition, segregation shall be prevented by the use of chutes, down pipes, trunking, baffles or other appropriate devices.

Forms for walls shall be provided with openings or other devices that will permit the concrete to be placed in a manner that will prevent segregation and accumulations of hardened concrete on the formwork or reinforcement above the level of the placed concrete.

When it is necessary to place concrete under water the Contractor shall submit to the Engineer his proposals for the method and equipment to be employed. The concrete shall be deposited either by bottom-discharging watertight containers or through funnel- shaped tremies which are kept continuously full with concrete in order to reduce to a minimum the contact of the concrete with the water. Special care shall be taken to avoid segregation.

If the level of concrete in a tremie pipe is allowed to fall to such extent that the water enters the pipe, the latter shall be removed from the pour and filled with concrete before being again lowered into the placing

position. During and after concreting under water, pumping or dewatering in the immediate vicinity shall be suspended if there is any danger that such work will disturb the freshly placed concrete.

(4) Interruptions to Placing

If the concrete placing is interrupted for any reason and the duration of the interruption cannot be forecast or is likely to be prolonged, the Contractor shall immediately take the necessary action to form a construction joint so as to eliminate as far as possible feather edges and sloping top surfaces and shall thoroughly compact the concrete in accordance with Clause 808. All work on the concrete shall be completed before elapse of initial setting time and it shall not thereafter be disturbed until it is hard enough to resist damage. Plant and materials to comply with this requirement shall be readily available at all time during concrete placing.

Before concreting is resumed after such an interruption the Contractor shall cut out and remedy all damaged or uncompacted concrete, feather edges or any undesirable features and shall leave a clean sound surface against which the fresh concrete may be placed.

If it becomes possible to resume concrete placing without contravening the Specification and the Engineer consents to a resumption, the new concrete shall be thoroughly worked in and compacted against the existing concrete so as to eliminate any cold joints.

In case of long interruption concrete shall be resumed as directed by Engineer.

(5) Dimension of Pours

Unless otherwise agreed by the Engineer, pours shall not be more than two meters high and shall as far as possible have a uniform thickness over the plan area of the pour. Concrete shall be placed to the full planned height of all pours except in the circumstances described in Sub-clause 807 (4).

The Contractor shall plan the dimensions and sequence of pours in such a way that cracking of the concrete does not take place due to thermal or shrinkage stresses.

(6) Placing Sequence

The Contractor shall arrange that the intervals between successive lifts of concrete in one section of the works are of equal duration. This duration shall not be less than three days or not more than seven days under temperate weather conditions unless otherwise agreed by the Engineer.

Where required by the Engineer to limit the opening of construction joints due to shrinkage, concrete shall not be placed against adjacent concrete which is less than 21 days old.

Contraction gaps in concrete shall be of the widths and in the locations as shown on the Drawing and they shall not be filled until the full-time interval shown on the Drawing has elapsed.

808 COMPACTION OF CONCRETE

Concrete shall be fully compacted throughout the full extent of the placed layer. It shall thoroughly worked against the formwork and around any reinforcement and other embedded item, without displacing them. Care shall be taken at arises or other confined spaces. Successive layers of the same pour shall be thoroughly worked together.

Concrete shall be compacted with the assistance of mechanical of immersion vibrators, unless the Engineer agrees another method.

Immersion and surface vibrators shall operate at a frequency of between 70 and 200 hertz. The Contractor shall ensure that vibrators are operated at pressures and voltages not less than those recommended by the manufacturer in order that the compactive effort is not reduced.

A sufficient number of vibrators shall be operated to enable the entire quantity of concrete being placed to be vibrated for the necessary period and, in addition, stand-by vibrators shall be available for instant use at each place where concrete is being placed.

Vibration shall be continued at each until the concrete ceases to contract, air bubbles have ceased to appear, and a thin layer of mortar has appeared on the surface. Vibrators shall not be used to move concrete laterally and shall be withdrawn slowly to prevent the formation of voids.

The vibrators shall be inserted vertically into the concrete to penetrate the layer underneath at regular spacing which shall not exceed the distance from the vibrator over which vibration is visibly effective and some extent of vibration is overlapped.

Vibration shall not be applied by way of reinforcement nor shall the vibrator be allowed to touch reinforcement, sheathing ducts or other embedded items.

809 CURING OF CONCRETE

(1) General

Concrete shall be protected during the first stage of hardening from loss of moisture and from the development of temperatures differentials within the concrete sufficient to cause cracking. Concrete shall be cured with wet cotton mat, sheet material or other compound for curing approved by the Engineer. The methods used for curing shall not cause damage of any kind to the concrete.

Curing shall be continued for as long as may be necessary to achieve the above objectives but not less than seven days or until the concrete is covered by successive construction whichever is the shorter period.

The above objectives shall be dealt with in Sub-clauses 809 (2) and 809 (3) but nothing shall prevent both objectives being achieved by a single method where circumstances permit.

The curing process shall commence as soon as the concrete is hard enough to resist damage from the process. In the case of large areas or continuous pours, it shall commence on the completed section of the pour before the rest of the pour is finished.

(2) Loss of Moisture

Exposed concrete surfaces shall be closely covered with impermeable sheeting, properly secured to prevent its removal by wind and the development of air spaces beneath it. Joints in the sheeting shall be lapped by at least 300 mm.

If it is not possible to use impermeable sheeting, the Contractor shall keep the exposed surfaces continuously wet by means of water spray or by covering with a water absorbent material which shall be kept wet, unless this method conflicts with Sub- clause 809 (3).

Water used for curing shall be of the same quality as that used for mixing.

Formed surfaces may be cured by retaining the formwork in place for the required curing period.

Alternatively, Approved curing compound shall be used to cover exposed surface**.**

If instructed by the Engineer, the Contractor shall, in addition to the curing provisions set out above provide a suitable form of shading to prevent the direct rays of the sun reaching the concrete surfaces for at least the first four days of the curing period.

(3) Limitation of Temperature Differentials

The Contractor shall limit the development of temperature differentials in concrete after placing by any means appropriate to the circumstances including the following:

a) limiting concrete temperatures at placing as set out in Sub-clause 811 (2);

b) use of low heat cement for mass concreting, subject to the agreement of the Engineer;

c) Leaving formwork in place during the curing period. Steel forms shall be suitably insulated on the outside;

d) Preventing rapid dissipation of heat from surfaces by shielding from wind.

810 PROTECTION OF FRESH CONCRETE

Freshly placed concrete shall be protected from rainfall and from water running over the surface until it is sufficiently hard to resist damage from these causes.

Concrete placed in the works shall not be subjected to any loading construction loads, impact, vibration, equipment movement, backfilling, hydraulic pressure, flowing water or other loading until it has attained at least its characteristic strength as defined in Clause 804.

811 CONCRETING IN HOT WEATHER

(1) General

The Contractor shall prevent damage to concrete arising from exposure to extreme temperatures, and shall maintain in good working order all plant and equipment required for this purpose

In the event that conditions become such that even with the use of equipment the requirements cannot be met, concrete placing shall immediately cease until such time as the requirements can again be met.

(2) Concrete Placing in Hot Weather

During hot weather the Contractor shall take all measures necessary to ensure that the temperature of concrete at the time of placing in the works does not exceed 30oC and that the concrete does not lose any moisture during transporting and placing.

Such measures may include but are not necessarily limited to the following:

a) Shielding aggregates from direct sunshine.

b) Use of a mist water spray on aggregates.

c) Sun shields on mixing plants and transporting equipment.

Surfaces in which concrete is to be placed shall be shielded from direct sunshine and surfaces shall be thoroughly wetted to reduce absorption of water from the concrete placed on or against them.

After concrete has been placed, the selected curing process shall be commenced as soon as possible. If any interval occurs between completion of placing and start of curing, the concrete shall be closely covered during the interval with polythene sheet to prevent loss of moisture.

812 CONSTRUCTION JOINTS

Whenever concrete is to be bonded to other concrete which has hardened, the surface of contact between the sections shall be deemed a construction joint.

Where construction joints are shown in the Drawing, the Contractor shall form such joints in such positions. The locations of joints, which the Contractor requires to make for the purpose of construction, shall be subject to the approval of the Engineer. Construction joints shall be in vertical or horizontal planes except in sloping slabs where they shall be normal to the exposed surface or elsewhere where the Drawing require a different arrangement.

Construction joints shall be arranged as to reduce to a minimum the effects of shrinkage in the concrete after placing, and shall be placed in the most advantageous positions with regard to stresses in the structures and the desirability of staggering joints.

Feather edges of concrete at joints shall be avoided. Any feather edges which may have formed where reinforcing bars project through a joint shall be cut back until sound concrete has been reached.

The intersections of horizontal and near horizontal joints and exposed faces of concrete shall appear as straight lines produced by use of a guide strip fixed to the formwork at the top of the concrete lift, or by other means acceptable to the Engineer.

Construction joints formed as free surfaces shall not exceed a slope of 20 per cent from the horizontal.

The surface of the fresh concrete in horizontal or near horizontal joints shall be thoroughly cleaned and roughened by means of high pressure water, and air jets or wire brush, when the concrete is hard enough to withstand the treatment without the leaching of cement. The surface of vertical or near vertical joints shall be similarly treated if circumstances permit the removal of formwork at a suitable time.

Where concrete has become too hard for the above treatment to be successful, the surface whether formed or free shall be thoroughly scabbled by mechanical means, manually or wet sand blasted and then washed with clean water. The indentations produced by scabbling shall not be less than 10 mm deep and shall be away from the finished face by 40 mm.

If instructed by the Engineer the surface of the concrete shall be thoroughly brushed with a thin layer of mortar composed of one part of cement to two parts of sand by weight and complying with Sub-clause 602(2) immediately prior to the deposition of fresh concrete. The mortar shall be kept just ahead of the fresh concrete being placed and the fresh layer of concrete shall be thoroughly and systematically vibrated to full depth to ensure complete bond with the adjacent layer.

No mortar or concrete shall be placed until the joint has been inspected and approved by the Engineer.

813 RECORDS OF CONCRETE PLACING

Records of the details of every pour of concrete placed in the works shall be kept by the Contractor in a form agreed by the Engineer. These records shall include class of concrete, location of pour, date and duration of pour, ambient temperature and concrete temperature at time of placing and all relevant meteorological information such as rain, wind etc., moisture contents of the aggregates, details of mixes batch numbers, cement batch number, results of all tests undertaken, part of the structure and place where test cube samples are taken from.

The Contractor shall supply to the Engineer four copies of these records each week covering work carried out the preceding week. In addition, he shall supply to the Engineer monthly histograms of all 28 day cubes strength results together with cumulative and monthly standard deviations, Coefficient of Variation, and any other information which the Engineer may require concerning the concrete placed in the works.

814 PLUM CONCRETE

(1) Materials

The size of the stone/rock shall not be larger than 200 mm measured in any direction. Concrete to be used in plum concrete shall be as specified in contract document.

(2) Construction

Composition of the plum concrete shall be 60 to 70 % M10 or M15 concrete and 40 to 30 % of stones by volume as specified in the contract document. The place to be filled up with the plum concrete shall be cleaned and chipped for adhesion with the concrete. Following completion of form work, a layer of concrete minimum 100 mm thick shall be laid upon over which clean and moist stones shall be placed at a distance of min 100 mm measured from face to face in any direction. The distance between the outer edge of the concrete mass and the nearest face of the stone to the edge shall not be less than 100 mm.

Then another layer of concrete having thickness not less than 100 mm measured from the top of the stone to the top surface of the layer shall be laid and compacted.

In case the proportion of concrete to stones is to be changed, the clear space between stones shall be adjusted as directed by the Engineer.

After compaction, again stones shall be placed on the layer as described above and the process shall be continued until the top layer of the concrete is completed. The placing of stones shall be staggered both in horizontal and vertical directions.

(3) Tests and Standard of Acceptance

Stones shall be tested for specific gravity and water absorption test. The test result shall meet the requirements as specified in these Specifications.

Concrete shall be tested as specified in Section 800.

815 REINFORCEMENT

(1) General

Reinforcement as plain bars, deformed bars and steel fabric shall comply with the following Standards.

NS: 191/ IS: 1786 for high strength deformed steel bars and wires. IS: 1566 for steel mesh fabric.

NS: 84/ IS: 432 mild steel and medium tensile steel bars.

All reinforcement shall be from an approved manufacturer and, if required by the Engineer, the Contractor shall submit the ISI certification mark or other test certificate from the manufacturer acceptable to the Engineer.

The sampling and frequency of testing shall be as set out in the NS: 84 and NS: 191. All reinforcement not complying with the Specification shall be removed from site.

(2) Storage of Reinforcement

All reinforcement shall be delivered to site either in straight lengths or cut and bent. No reinforcement shall be accepted in long lengths which have been transported bent over double.

Any reinforcement which is likely to remain in storage for a long period shall be protected from the weather so as to avoid corrosion and pitting. All reinforcement which has become corroded or pitted to an extent which, in the opinion of the Engineer, will affect its properties shall either be removed from site or may be tested for compliance with the appropriate Indian Standard in accordance with Sub-clause 815 (1) at the Contractor expense.

Reinforcement shall be stored at least 150 mm above the ground on clean area free of mud and dirt and sorted out according to category, quality and diameter.

(3) Bending Reinforcement

Unless otherwise shown on the Drawing, bending and cutting shall comply with IS: 2502.

The Contractor shall satisfy himself as to the accuracy of any bar bending schedules supplied and shall be responsible for cutting, bending, and fixing the reinforcement in accordance with the Drawing.

Bars shall be bent mechanically using appropriate bar benders. Bars shall be bent cold by the application of slow steady pressure. At temperature below 5oC the rate of bending shall be reduced if necessary to prevent facture in the steel. Bending reinforcement inside the forms shall not be permitted except for mild steel bars of diameter less or equal to 12 mm, when it is absolutely necessary.

After bending, bars shall be securely tied together in boundless or groups and legibly labelled as set out in IS: 2502.

(4) Fixing Reinforcement

Reinforcement shall be thoroughly cleaned. All dirt, scale, loose rust, oil and other contaminants shall be removed before placing it in position. If the reinforcement is contaminated with concrete form previous operation, it shall be cleaned before concreting in that section.

Reinforcement shall be securely placed and fixed in position as shown in the drawing or directed by the Engineer.

Unless otherwise agreed by the Engineer, all intersecting bars shall be either tied together with not less

than 1.6 mm diameter soft annealed iron wire and the end of the wire turned into the body of the concrete, or shall be secured with a wire clip of a type agreed by the Engineer.

Spacer blocks shall be used for ensuring that the correct cover is maintained on the reinforcement. Blocks shall be as small as practicable and of a shape agreed by the Engineer. They shall be made of mortar mixed in the proportions of one part of cement to two parts of sand by weight. Wires cast into the block for tying in to the reinforcement shall have not less than 1.6 mm diameter and shall be soft annealed iron.

Alternatively, another type of spacer block may be used subjected to the Engineer's approval.

All reinforcement shall be checked of shape, size, diameter and number where necessary. Reinforcement shall be rigidly fixed so that it remain intact during placing of concrete. Any fixers made to the formwork shall not remain within the space to be occupied by the concrete being placed.

No splices shall be made in the reinforcement except where shown on the Drawing or agreed by the Engineer. Splice lengths shall be as shown on the Drawing or directed by the Engineer.

Reinforcement shall not be welded except where required by the contract or agreed by the Engineer. If welding is employed, all welded splices shall be full penetration butt welds complying with the procedures set out in IS: 2751 or IS: 9417 as applicable. Mechanical splices shall not be used unless the Engineer agrees otherwise. Acceptance for welded or mechanical splices of approved design shall be based on qualification tests to be carried out by the Contractor prior to start of the work. Construction control testing as instructed by the Engineer shall be also carried out.

The Contractor shall ensure that reinforcement left exposed in the works shall not suffer distortion, displacement or other damage. When it is necessary to bend protruding reinforcement aside temporarily, the radius of the bend shall not be less than four times the bar diameter for mild steel bars of six times the bar diameter for high yield bars. Such bends shall be carefully straightened without leaving residual kinks or damaging the concrete round them before concrete placing. In no circumstances heating and bending of high yield bars shall be permitted.

Bars complying with IS: 1786 or other high tensile bars shall not be bent after placing in the works.

816 CONCRETE FOR SECONDARY PURPOSES

(1) Non-structural Concrete

Non-structural concrete (NS concrete) shall be used only for non-structural purposes where shown on the Drawing.

NS concrete shall be compound of ordinary Portland cement and aggregate complying with this Specification.

The weight of cement mixed with 0.3 cubic metres of combined aggregate shall not be less than 50 kg. The mix shall be proportioned by weight or by volume. The maximum aggregate size shall be 40 mm nominal.

The concrete shall be mixed by machine or by hand in accordance with Sub-clause 816 (3) to a uniform color and consistency before placing. The quantity of water used shall not exceed that required to produce a concrete with sufficient workability to be placed and compacted where required.

The concrete shall be compacted by hand towels or rammers or by mechanical vibration.

(2) No Fines Concrete

No fines concrete (NF concrete) is intended for use where a porous concrete is required and shall only be used where shown on the Drawing or instructed by the Engineer.

The mix shall consist of Ordinary Portland cement and aggregate complying with this Specification. The aggregate size shall be 40 mm to 10 mm only. The weight of cement mixed with 0.3 cubic metres of aggregate shall not be less than 50 kg. The quantity of water shall not exceed that required to produce a smooth cement paste which will coat evenly the whole of the aggregate.

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(3) Hand Mixed Concrete

Concrete for structural purposes shall not be mixed by hand. Where non-structural concrete is required, hand mixing may be carried out subject to approval of the Engineer.

For making hand mixed concrete, cement sand and aggregate shall be batched separately by volume or by weight as applicable. Then cement and sand shall be mixed dry to uniform colour. The aggregate shall be stacked in a proper shape upon which cement sand mix shall be spread and whole mix shall be turned up and down to have uniform mix of all ingredients. Then water shall be added as specified in Sub-clause 816 (1) and shall be mixed to uniform consistency.

For hand mixed concrete the specified quantities of cement shall be increased by 10% and not more than 0.25 cubic meter shall be mixed at one time. During windy weather precautions shall be taken to prevent cement from being blown away in the process of gauging and mixing.

817 EARLY LOADING

No load shall be applied to any part of a structure until the specified curing period has expired, and thereafter loading shall be allowed after approval by the Engineer. The Engineer's decision shall be based on the type of load to be applied, the age of concrete, the magnitude of stress induced and the propping of the structure.

Concrete structures shall not be subjected to construction loads, hydraulic pressure, impounding, flowing water, backfilling, vibration or other service conditions before the concrete has attained sufficient strength and maturity as approved by the Engineer.

818 TEST AND STANDARD OF ACCEPTANCE

(1) General:

Concrete shall conform to the surface finish and tolerance as prescribed in these specifications for respective components.

Random sampling and lot by lot of acceptance inspection shall be made for the 28 days' cube strength of concrete.

Concrete under acceptance shall be notionally divided into lots for the purpose of sampling, before commencement of work. The basis of delimitation of lots shall be as follows;

i. No individual lot shall more than 30 cu.m. in volume
ii. Different grades of mixes of concrete shall be divided into separate lots
iii. Concrete of a lot shall be used in the same identifiable component of the structure

(2) Sampling and testing

Concrete for making test cubes shall be taken from a batch of concrete at point of delivery into construction, according to procedure laid down in IS: 1199.

A random sampling procedure to ensure that each of the concrete batches forming the lot under acceptance inspection has equal chance of being chosen for taking cubes 150 mm cubes shall be made, cured and tested at the age of 28 days for compressive strength in accordance with IS: 516. The 28-day test strength result for each cube shall form an item of the sample. Test at other age also shall also be performed, if specified.

Where automated batching plant/ Ready Mixed Concrete Plant is located away from the place of use and the time gap between production and placement is more than initial setting time or where any ingredients are added subsequent to mixing, separate set of samples shall be collected and tested at batching plant and at location of placement. The results shall be compared and used to make suitable adjustment at batching plants so that properties of concrete at placement are as per the requirements.

(3) Test specimen and sample strength:

Three test specimens shall be made from each sample for testing at 28 days. Additional cubes maybe required for various purposes such as to determine the strength of concrete at 7 days or for any other purpose.

The test strength of the sample shall be the average of the strength of 3 cubes. The individual variation should not be more that ± 15 per cent of the average. If variation is more, the test results of the sample are invalid.

The minimum frequency of sampling of concrete of each grade shall be in accordance with Table 8.10.

Table 8.10: Control Test and their Minimum Frequency of Concrete

S No	MATERIALS	TESTS	FREQUENCY
1	Cements	Acceptance tests	• Conservative samples for each supply and not less than every 200 t or part of it
		Control tests: Chemical Composition Physical Properties	• Testing in case of noncompliance of the mixes or storage on site for longer than 1 month
2	Aggregates	• Acceptance tests: • Control Tests:	
		Grading, Silt & clay content and Organic Impurities	• 1 set (3 nos) test for each 10 to 50 cum and additional test for each 50 cum of concrete for fine aggregate. • 1 set (3 nos) test for each 25 to 125 cum and additional test for each 125 cum for coarse aggregate.
		Chloride content	• As frequently as Required
		Sulphate content, Alkali reactivity, Water, Admixtures	• As frequently as Required
3	Concrete	• Lab Trials • Site Trials • Control Tests • Compressive Strengths	• For 1-5 cum quantity of work at one place 1 set, • For 5.1-15 cum quantity of work at one place 2 set • For 15 .1 to 30 cum quantity of work at one place 3 set • For 30 .1 to 50 cum quantity of work at one place 4 set • For more than 50 cum quantity of work at one place 4 set of sample plus one additional for each 50 cum or part thereof • Early works every 6 cum or part of it
4	Reinforcement	• Mechanical properties • 0.2 percent proofstress/ yield stress, • Tensile strength/yield strength ratio • Elongation	• For 1-25 bundles lot 3 rod (one from each bundle) from randomly selected 3 bundles. • For 26-65 bundles lot 4 rod (one from each bundle) from randomly selected 4 bundles • For 66-180 bundles lot 5 rod (one from each bundle) from randomly selected 5 bundles • For 181- 300 bundles lot 7 rod (one from each bundle) from randomly selected 7 bundles • For > 300 bundles lot 10 rod (one from each bundle) from randomly selected 10 bundles

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(4) Acceptance criteria

(a) Compressive Strength

I.Cubes

The concrete shall be deemed to comply with the specified characteristic compressive strength when both the group mean check and individual test result conditions meet the Cube Strength Compliance Values set out in Table 8.4.

II.Cores

When the concrete does not satisfy both the condition given in I above, representative cores shall be extracted from the hardened concrete for compression test in accordance with the method described in IS: 1199 and tested to establish whether the concrete satisfies the requirement of compressive strength.

Evaluation of compressive strength by taking cores may also be done in case of doubt regarding the grade of concrete used either due to poor workmanship or based on result of cube strength tests the locations from which core samples

are to be taken and their number shall be decided so as to be representative of the whole of the concrete under consideration. However, in no case shall fewer than three cores be tested. Cores shall be prepared and tested as described in IS: 516. Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85 percent of the cube strength of the grade of concrete specified for the corresponding age and no individual core has strength less than 75 percent of the specified strength.

(b) Chloride and Sulphate Content

Where Chloride and Sulphate is specified, the total chloride and sulphuric anhydride (SO_3) content of all the constituents of concrete as a percentage of mass of cement in the mix shall not exceed the values given in this Section of the specifications.

(c) Density of Fresh Concrete

Where minimum density of fresh concrete is specified, the mean of any four consecutive non-overlapping samples shall not be less than the specified value and any individual sample result shall not be less than 97.5 per cent of the specified value.

(d) Density of Hardened Concrete

Where minimum density of hardened concrete is specified, the mean of any four consecutive non – overlapping samples shall not be less than the specified value and any individual sample result shall not be less than 97.5 per cent of the specified value.

(e) Permeability Test

Where Permeability of concrete is specified, water Permeability test as per DIN: 1048 Part 5 – 1991 shall be carried out as described below

I. A cylindrical test specimen 150 mm dia and 160 mm high shall be prepared.

II. After 28 days of curing, the test will be conducted between 28 and 35 days. The test specimen shall be fitted in a machine such that the specimen can be subjected to a water pressure upto7 bars.

III. The concrete specimen shall be subjected to a water pressure of 0.5 N/mm2 from the top for the period of 3 days. The pressure shall be maintained constant throughout the test period. If the water penetrates through to the underside of the specimen, the test may be terminated and the specimen rejected as fail.

IV. After 3 days, the pressure shall be released and the sample shall be taken out. The specimen shall be split in the middle by compression applied on two round bars on opposite sides above and below.

V. When the split faces show signs of drying (after 5 to 10 minutes) the maximum depth of penetration in the direction of height shall be measured with the scale and extent of water penetration established.

VI. The mean of maximum depth of penetration obtained from three specimens thus tested, shall be taken as the test result and it shall not exceed 25 mm

If the concrete is not able to meet any of the standards of acceptance as prescribed, the effect of such deficiency on the structure shall be investigated by the Contractor as directed by the Engineer. Any additional work required by the Engineer for such acceptance shall be carried out by the Contractor at his cost. In such case payment for such work shall be made at reduced rate proportional to reduced strength rate. In case the concrete is not found to be acceptable even after investigation, the Contractor shall remove the rejected concrete forthwith.

819 WATER PROOFING AND ASPHALT APPLICATION

A. FIBRE REINFORCED ELASTOMERIC LIQUID WATER PROOFING MEMBRANE WITH RESILIENT ACRYLIC POLYMERS

1. Material

Fiber reinforced elastomeric liquid water proofing membrane is a ready-to-use waterproofing, white product, with high solar reflectance and Sun Reflectivity Index (SRI) of 105, for external applications. This is made from resilient acrylic polymers and synthetic resins in water dispersion, and when dry forms a continuous, flexible waterproofing membrane. This is resistant to all atmospheric conditions and UV rays, and guarantees long lasting protection for the substrate.

2. Technical Specification/ Parameters

(1) Fiber reinforced elastomeric liquid water proofing membrane with fibers in water emulsion with high reflectance and emissivity with a solar reflectance index SRI of 105 should comply with the requirements of EN 1504-9 (“Products and systems for protecting and repairing concrete structures: definitions, requirements, quality control and conformity assessment. General principles for the use of products and systems”) EN 1504-2 coating (C) principles PI, MC and IR (“Concrete surface protection systems”).

(2) This should possess a paste like consistency having highly reflective white color.

(3) This should have density of 1.35 with dry solid content of 61.4%.

(4) This should have minimum tensile strength of 1.0N/mm² as per ISO 37 or ASTM D-412.

(5) This should confirm to results after testing as per EN1062-11 for exposure to artificial weather conditions.

(6) The Sun Reflectivity Index when tested as per ASTM E1980 should be 105 minimum.

(7) Elongation at break (% age) of 150 % minimum as per ASTM D-412.

(8) Adhesion strength is more than 1.0 N/mm2 as per ASTM D-4541.

3. Applications

It is to be applied using a long-haired roller, brush or spray on any horizontal, sloping or vertical surfaces to form a string, flexible, tack-free dry surface, suitable for occasional light foot traffic. This can with stand normal expansion and contraction stresses caused by temperature variations due to its flexibility. This also helps lower the working temperature of roofs and guarantees good energy performance properties of all

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the layers of the roof.

4. Preparation of Surface

All the substrates, whether they are new or old, must be sound, clean, dry and free of all traces of oil, grease, old paint, rust, mould and nay other material which could compromise the bond. Application temperature may be from 70C to 400C.

Concrete and in general mineral substrates must be sound and dry with no rising damp. Any loose parts must be removed with wire brushes. All wax, water-repellent treatments, etc. must be removed from the surface of ceramic substrates with a suitable detergent and/ or by sanding. Any hollows and gaps in the surface must be repaired properly with appropriate material as described and instructed by the manufacturer of this product. The tools to be used must be properly cleaned.

5. Application Procedure, Measurement and Payment

All the area of operation shall be thoroughly cleaned. Mix the content in such a manner that they are perfectly blended into a homogenous state of liquid which can be applied by long haired roller or airless spray. The fibre reinforced elastomeric liquid water proofing membrane with resilient acrylic polymers shall be applied on top of concrete roof in three coats @ 10.76 litre/10 sqm or more as recommended by manufacturer specification. One coat i.e. first coat of self-priming elastomeric water proofing liquid. The material shall be diluted with water in the ratio of 3:1 (3 parts of elastomeric water proofing liquid and 1 part of water). Wait until the first coat is completely dry and becomes slightly darker in colour. After the first coat has dried completely apply second coat with undiluted elastomeric water proofing liquid in a cross direction to the previous coat. After the drying of second coat completely apply the final coat of undiluted elastomeric water proofing liquid in a direction perpendicular to previous coat. The overall dry film thickness should not be less than 500 microns or more as specified in manufacturer specification. Protect the membrane from rain unless it is completely dry. The overall consumption of the material should be as per nomenclature of the item and should also adhere to the specifications detailed in the approved schedule of the manufacturer.

Measurement and Payment

The length and breadth/ height shall be measured in running meter correct to two places of decimal and the area of applications should be measured in sqm correct to two places of decimal. The unit of measurement of area of application shall be square meter unless otherwise specified.

The unit rate shall include the cost of all the labour and material involved in all the operations described above. The payment shall be made as per unit rate specified in BoQ.

B. APPLICATION OF ASPHALT

1. General

Asphalt provides excellent waterproofing, preventing leaks and protecting the underlying structure from moisture damage. It withstands various weather conditions, including rain, snow, and UV exposure, contributing to a long lifespan for roofs. Asphalt can accommodate temperature fluctuations and structural movement, reducing the risk of cracking. Asphalt to be used for roofing should be of high quality to provide excellent water proofing and good bonding.

2. Melting of Asphalt

Asphalt melting refers to the process of heating asphalt to transform it from a solid to a liquid state, making it easier to work with for applications such as roofing, paving, and maintenance. Asphalt typically melts at temperatures between 250°F and 350°F (121°C to 177°C), depending on the specific type and formulation. Asphalt can be melted using direct heating or indirect heating as follows:

Direct Heating: Using a flame or hot air to melt the asphalt. This method requires careful control to avoid overheating.

Indirect Heating: Using heated equipment, like tanks or kettles, to warm the asphalt without direct flame

exposure.

3. Application

Melted asphalt is common in the installation of asphalt-based roofing systems, allowing for proper adhesion of materials. It is also used in patching and sealing cracks in existing surfaces.

4. Measurement and Payment

The length and breadth shall be measured in running meter correct to two places of decimal and the area of applications should be measured in sqm correct to two places of decimal. The unit of measurement of area of application shall be square meter unless otherwise specified.

The unit rate shall include the cost of all the labour and material involved in all the operations described above. The payment shall be made as per unit rate specified in BoQ.

820 MEASUREMENT

(1) Concrete

Concrete laid in place as specified in the Drawing or directed by the Engineer shall be measured in cubic metres separately for each class. No deduction shall be made in the measurement for:

a. bolt holes, pockets, box outs an cast in components provided that the volume of each is less than 0.15 cubic metres;

b. mortar beds, fillets, drips, rebates, recesses, grooves, chamfers and the like of 100 mm total width or less;

c. reinforcement

(2) Blinding Concrete/Non Structural Concrete

Blinding concrete laid in place shall be measured in cubic meter. No deduction shall be made for openings provided that the area of each is less than 0.5 square metres. Blinding concrete over hard material shall be measured as the volume used provided that the maximum thickness of 150 mm allowed for over break in not exceeded.

(3) Admixtures, Workability and Hardening Agents and Curing Compounds

Unless stated otherwise, rate of concrete shall deemed to include admixture, workability, hardening agent and curing compounds.

(4) Plum Concrete

Unless specified otherwise plum Concrete shall be measured in cu.m. Form work struts, bracing supports etc. shall be measured separately as it is not deemed to be included in the measurement of plum concrete.

(5) Reinforcement

All types of reinforcement shall be measured in length including hooks, if any, separately for different diameters as actually used in works or as directed by the Engineer, excluding overlaps. From the length so measured, the weight of reinforcement shall be calculated in ton on the basis of IS: 1732.

Wastage, overlaps, couplings, welded joints, spacer bars, chairs, stays, hangers and annealed steel wire or other method for binding and placing shall not be measured and cost of these items shall be deemed to be included in the rates for reinforcement.

An average weight of at least 5 samples each one metre length shall be determined by the laboratory approved by the Engineer. The weight of each type of the reinforcement shall be determined by multiplying average weight of the respective reinforcement by its length.

(6) Fabric Reinforcement

Fabric reinforcement laid as per Drawing or as directed by the Engineer shall be measured in square meter. No allowance shall be made for laps and wastage.

821 PAYMENT

(1) Concrete

Every class of concrete shall be paid as per respective contract unit rate. In addition to those specified in Clause 115 the respective rate shall also include the cost of:

a) All materials including admixture and workability agent, curing agent, labour, Tools, Plants and equipment required for mixing, transporting and placing in position, vibrating and compacting, finishing and curing including all incidental expenses.

b) Unless mentioned separately as an item in contract sampling and testing, quality assurance and supervision

c) Unless mentioned separately as an item in contract, cost of providing, fixing, and removing formwork, Staging required for concrete work as per Section 900 of this specification.

d) Placing and compacting against excavated surfaces where required including any additional concrete to fill over break and working space.

e) Complying with the requirements of Clauses 801 to 813.

(2) Plum Concrete

Plum concrete shall be paid as per contract unit rate of the respective item which shall be the full and the final compensation to the Contractor as per Clause 115 to complete the works as per these Specifications.

(3) Reinforcement

The reinforcement shall be paid at contract unit rate. In addition to those specified in Clause 115 the rate shall also include compensation for the cost of providing, cutting to length, splice lengths additional to those shown on the Drawing, laps, bending, hooking, waste incurred by cutting, cleaning, spacer blocks, provision and fixing of chairs or other types of support, welding, fixing the reinforcement in position including the provision of wire or other material for supporting and tying the reinforcement in place, bending reinforcement aside temporarily, and straightening, place and compacting concrete around reinforcement and for complying with Clause 815.

(4) Fabric Reinforcement

The fabric reinforcement shall be paid at contract unit rate which shall be also inclusive of compensation for wastage and laps.

SECTION 900: FORMWORK

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901 SCOPE AND DEFINITIONS

This Section covers the preparation, construction and removal of formwork in general and false work in some special case for concrete structures. It also covers the quality requirements for surface finish on formed and unformed surfaces.

Definitions used in this Clause and other relevant Clause of this Section and other relevant Sections of these Specifications are as follows:

- Formwork means the surface against which concrete is placed to form a face. All the immediate support necessary to retain the surface in position while concrete is placed, shall be treated an integral part of formwork.
- False work means the structural elements supporting both the formwork and the concrete until the concrete becomes self-supporting.
- A formed face is one which has been cast against formwork.
- An unformed surface means a horizontal or nearly horizontal surface which is not cast against form work.
- An exposed face is one which will remain visible when construction has been completed.

902 GENERAL

The Contractor shall be responsible for designing and construction of formwork and false work so that they will support the loads imposed on them by the fresh concrete together with additional stresses imposed by vibrating equipment and by construction traffic, and so that after the concrete has hardened the formed faces shall be in the positions shown on the Drawing within the tolerances set out in Clause 905.

Before construction begins, the Contractor shall submit to the Engineer Drawing showing details of the proposed formwork and false work as the case may be in accordance with this Section and other relevant Section of these Specification.

For formwork and falsework associated with works over or adjacent to rivers, canals, drains, waterways, aqueducts, culverts or other watercourses, the Contractor shall provide adequate measures against flooding, scour, undermining, impact and other hydraulic or construction hazards.

903 FORMWORK FOR CONCRETE

(1) Construction of Formwork

Joints in formwork for exposed faces shall, unless otherwise specified, be evenly spaced and horizontal or vertical and shall be continuous in a regular pattern.

All joints in formwork shall be watertight. Where reinforcement projects through formwork, the form shall fit closely round the bars.

Formwork shall be so designed that it may be easily removed from the work without damage to the faces of the concrete. It shall also incorporate provisions for making minor adjustments in position, if required, to ensure the correct location of concrete faces. Due allowance shall be made in the position of all formwork for movement and settlement under the weight of fresh concrete.

Surfaces at slopes less than 20° may be formed by screeding. Surfaces at slopes between 20° and 30° shall generally be formed if the Contractor can demonstrate to the satisfaction of the Engineer that such slopes can be screeded with the use of special screed boards to hold the concrete in place during vibration.

Horizontal or inclined formwork to the upper surface of concrete shall be adequately secured against uplift due to the pressure of fresh concrete. Formwork shall also be tied down or otherwise secured against floating within the body of the concrete.

The internal and external angles on concrete surfaces shall be formed with fillets and chamfers of the sizes

shown on the Drawing unless otherwise instructed by the Engineer.

Supports for formwork may be bolted to previous placed concrete provided the type of bolt used is acceptable to the Engineer. If metal ties through the concrete are used in conjunction with bolts, the metal left in shall not be close to the face of the concrete by less than 50 mm.

Formwork shall not be re-used after it has suffered damage as it will impair the finished surfaces of the concrete. Where circumstances prevent easy access within the form, temporary openings shall be provided through the formwork for cleaning and inspection.

Shear keys of the size and shape as indicated on the Drawing shall be provided in all construction joints.

Where precast concrete elements are specified for use as permanent formwork, or proposed by the Contractor and agreed by the Engineer, they shall comply with the requirements of formwork as specified in the Specification in respect of surface finish, strength and rigidity. Such elements shall be set true to line and level within the tolerances prescribed for the appropriate class of finish in Clause 906 and fixed so that they cannot move when concrete is placed against them.

(2) Preparation of Formwork

Before any reinforcement is placed into position within formwork, the formwork shall be thoroughly cleaned and then dressed with a release agent. The agent shall be either a suitable oil incorporating a wetting agent, an emulsion of water suspended in oil or a low viscosity oil containing chemical agents. The Contractor shall not use an emulsion of oil suspended in water nor any release agent which causes staining or discoloration of the concrete, air holes on the concrete surface, or retards the set of the concrete or affects the strength of concrete.

In order to avoid colour differences on adjacent concrete surfaces, only one type of release agent shall be used in any one section of the works.

In cases where it is necessary to fix reinforcement before placing formwork, all surface preparation of formwork shall be carried out before it is placed into position. The Contractor shall not allow reinforcement or pre-stressing tendons to be contaminated with formwork release agent.

Before placing concrete all dirt, construction debris and other foreign matter shall be removed completely from within the placing area.

Before concrete placing commences, all wedges and other adjusting devices shall be secured against movement during concrete placing and the Contractor shall maintain a watch on the formwork during placing to ensure that no movement occurs. If any movement noticed, the formwork shall be set right immediately.

(3) Removal of Formwork

Formwork shall be carefully removed without shock or disturbance to the concrete. No formwork shall be removed until the concrete has gained sufficient strength to withstand any stresses safely to which it may thereby be subjected.

The minimum periods which shall elapse between completion of placing concrete and removal of forms are given in Table 9.1 and apply to ambient temperatures higher than 10oC. At lower temperatures or if cement other than ordinary Portland are involved, the Engineer may instruct longer periods.

Alternatively, formwork may be removed when the concrete has attained the strength set out in Table 9.1, provided that the attained strength is determined by making test cubes and curing them under the same conditions as the concrete to which they refer.

Compliance with these requirements shall not relieve the Contractor of his obligation to delay removal of formwork until the removal can be completed without damage to the concrete.

If the Contractor wishes to strip formwork from the underside of arches, beams and slabs before the expiry of the period for supports set out above, it shall be designed so that it can be removed without disturbing

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the supports. The Contractor shall not remove supports temporarily for the purpose of stripping formwork and subsequently replace them.

As soon as the formwork has been removed, bolt holes in concrete faces other than construction joints which are not required for subsequent operations shall be completely filled with mortar sufficiently dry to prevent any slumping at the face. The mortar shall be mixed in the same proportions as the fine aggregate and cement in the surrounding concrete and with the same materials and shall be finished flush with the face of the concrete.

After laying of the formwork and casting of concrete thereby, the date of casting of concrete shall be marked on the surface of related concrete by water proof paint/marker for estimation of curing time and removal time of formwork.

Table 9.1: Minimum Periods for Formwork Removal

Position of Formwork	**Minimum period for Temperatures over 10° C**	**Strength to be attained**
Vertical or near vertical faces of mass Concrete	24 hours	0.2 fck
Vertical or near vertical faces of reinforced	48 hours	0.3 fck
Underside of arches beams and slabs (formwork only)	4 days	0.5 fck
Supports to underside of arches, beams and slabs	14 days	f_{ck}
Arched linings in tunnels and underground works	24 hours	4 N/mm^2

Note: f_{ck} is the Characteristic Strength for the class of concrete used.

904 FALSEWORK

(1) Design and Drawing

The design of all falsework required for the construction of permanent works, including falsework for aqueducts, canal structures, cross-drainage structures, culverts, intakes, outlets, bridges, river training structures and other structures shall conform to the requirements of this Clause.

Detailed working drawing in triplicate and design calculations for false work shall be furnished by the Contractor to the Engineer.

No false work construction shall start until the Engineer has reviewed and approved the Drawing. The Contractor shall provide sufficient time for the Engineer to complete this review.

Such time shall be proportionate to the complexity of the false work design and in no case shall be less than two weeks. The Contractor may revise the false work drawing at any time provided sufficient time is allowed for the Engineer's review and approval, before construction is started on the revised portion.

(a) False work Drawing

The false work drawing shall include but not limited to the following: -

(i) Details of openings, waterways, canal passages, temporary access arrangements and other clearances required for construction and operation of the works.

(ii) Diagram showing proposed concrete placing sequence and construction joints location.

(iii) Assumed values of soil bearing capacity for both wet and dry conditions, as determined by the Contractor.

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(iv) Anticipated total settlements of false work and forms.

(v) Details of drainage, if any.

(vi) Details of drainage protection (or scouring/undermining protection) of footing and/or foundations, including locations of existing utilities, excavations, recent fills if any.

(vii) Details of all elements required to insure the free movements of concrete due to shrinkage.

(viii) Details of joints, bracing and major arrangements to insure vertical and horizontal stability in all direction and at all stages of operations.

(ix) Manufacture's recommendations and/or other operating recommendations as required for the justifications for the design.

When a schedule for placing concrete is shown on the contract plans, no deviation shall be permitted there from unless approved in writing by the Engineer.

Anticipated total settlement shall not exceed 25 mm. This shall include false work footing settlement and joints take-up.

(b) False work Calculation

The calculations must show the stresses & deflections of all supporting members. The design of false work shall be based upon the maximum loads, the maximum stresses and deflections and the conditions listed below. The stresses listed are based upon the use of undamaged high quality materials and such stresses shall be reduced by the Contractor if lesser quality materials are to be used. The Contractor shall be responsible for the proper evaluation of his false work material and design of false work to carry safely the actual loads imposed.

(i) The design loads for false work shall consist of the sum of dead and live vertical loads and horizontal load.

(ii) The vertical design loads for the combined live and dead loads shall not be less than the actual required loads with due allowance for dynamic loads. However, it shall not be less than 0.5 t/m2.

(iii) Dead load shall include the weight of concrete, reinforcing steel, forms and false work.

(iv) Live load shall consist of the actual weight of the equipment to be supported by false work, applied as concentrated loads, at the points of contact and a uniform of and less than 0.1 t/m2 applied over the area supported, plus 0.11t/lm applied at the outside edges of deck overhangs.

(v) The horizontal loads to be resisted in any direction by diagonal bracing, ties or other means approved by the Engineer shall not be less than 2 percent of the total dead load.

(vi) False work footing shall be designed to carry the load imposed upon them without exceeding the estimated soil bearing capacity and anticipated settlements.

(vii) If the concrete is to be pre stressed, the false work shall be designed to support increased or readjusted loads caused by the pre stressing forces.

(viii) Joists supporting slabs and overhangs shall be considered as false work and they shall be designed for the maximum loading and deflections loading and deflections permissible on jacks, brackets, columns joist and other manufactures devices shall not exceed the manufacturer's recommendations and in all cases their deflections shall be less than 1/270 of their clear span.

If requested by the Engineer, the Contractor shall furnish catalogue data listing the manufacturer's recommendations for manufactured devices and perform tests as necessary to demonstrate the adequacy of any such device proposed for use.

False work designed for pre-stressed concrete shall allow for the required free movements during pre-stressing operations.

When footing foundations are to be used, the bearing capacity of the soils shall be determined by the Contractor using the Plate Load Test method. The soil surface must be prepared adequately to allow for a relevant implementation of this test. Tests shall be carried out in both dry and wet conditions.

(c) Falsework for Aqueducts, Canal Structures and Hydraulic Structures

Falsework for aqueducts, canal structures, cross-drainage structures, intakes, outlets, stilling basins, falls, siphons, culverts and other hydraulic structures shall be designed to support all loads imposed during construction without excessive settlement, displacement or deformation.

The design shall consider the weight of fresh concrete, reinforcement, formwork, construction equipment, construction loads, vibration, water pressure and other applicable temporary loads.

Falsework for curved, inclined, sloping or irregular hydraulic surfaces shall be accurately fabricated and securely supported to maintain the lines, levels, dimensions and profiles shown on the Drawings.

Particular care shall be taken to maintain the specified hydraulic cross-section, invert level, bed level, side slopes and transitions of canals, aqueducts and other water-carrying structures.

(d) False work over or Adjacent to Roadways

In addition to the minimum requirements specified above, false work over or adjacent to roadways, where false work opening is specified, shall be designed and constructed so that the false work will be stable if subjected to impact by vehicles. The false work design in such cases shall include, but not be limited to the following minimum provisions:

(i) The vertical design load of false work bents, including footing and caps which support the portion of the false work over openings shall be increased to not less than twice the design load calculated in accordance with Sub-Clause 904 (1) (b).

(ii) Each false work post adjacent to openings shall be securely anchored to its withstand footing or otherwise laterally restrained at its base so as to withstand a 0.9t force applied at the base of the post in any direction except toward the road track.

(2) Construction

The false work shall be constructed to substantially conform to the false work Drawing. The materials used in the false work construction shall be of the quality necessary to sustain the stresses required by the false work design.

The workmanship used in false work construction shall be of such quality that the false work will support the loads imposed on it without excessive settlement to take-up beyond that shown on the false work Drawing. False work shall be founded on a solid footing safe against undermining protected under softening, and capable of supporting the loads imposed on it. When false work is supported on piles, the piles shall be driven to a bearing value determined in accordance with IS 2911.

When false work is over or adjacent to roadways or waterways, all details of the false work system which contribute to horizontal stability and resistance to impact shall be installed at the time each element of the false work is erected and shall remain until the false work is removed.

Suitable jacks or wedges shall be used in connection with false work to set the forms at the required grade and to take up excessive settlement in the false work either before or during the placing of concrete.

Comber strip shall be used as approved by the Engineer, to compensate the false work deflection, vertical alignment and anticipated structure deflection. The Contractor shall provide tell-tales attached to the soffit and readable from the ground, in enough systematically placed locations to determine the total settlement of the entire portion the structure where the concrete is being placed.

Should unanticipated events occur, including settlements that deviate more than plus or minus 10 mm from those indicated on the false work Drawing, which in the opinion of the Engineer would prevent obtaining a structure conforming to the requirements of this Specification, the placing of concrete shall be discontinued

until corrective measures satisfactory to the Engineer are provide. In the event satisfactory measures are not provided prior to the initial set of the concrete in the affected area, the placing of concrete shall be discontinued at a location determined by the Engineer. All unacceptable concrete shall be removed.

The Contractor shall be responsible for the maintenance of false work throughout the construction.

(3) Removal

False work shall not be released before the requirements of Sub-clause 903 (3) are fulfilled. False work for cast-in-situ pre-stressed concrete shall be released according to the pre- stressing sequences shown on the Drawing. False work shall be removed uniformly and gradually to permit the structure to take its load slowly and evenly.

All false work material shall be removed. False work pilling shall be removed up to at least 600 mm below the surface of the original ground or the bottom or side slope of excavated areas.

(4) False work for Steel Structures

False work for steel structures shall comply with the requirements of Sub-clause 904(1) to 904 (4) in addition to the requirements of this Sub-clause.

False work and forms shall be constructed so that any loads applied to girder webs shall be applied within a distance to a flange or stiffener approved by the Engineer and shall be distributed in a manner that will not produce local distortion of the web.

Temporary struts and ties shall be provided as necessary to resist lateral loads applied to the girder flanges and prevent appreciable relative vertical movement between the edge of deck forms and the adjacent steel girder.

905 SURFACE FINISH ON FORMED SURFACES

(1) Class of Finish

The surface finish to be achieved on formed concrete surfaces shall be as shown on the Drawing and are defined hereunder: -

(a) Class F1 Finish

This finish is for surfaces against which backfill or further concrete will be placed. Formwork may be sawn boards, sheet metal or any other suitable material which will prevent the loss of laitance from the concrete being placed.

(b) Class F2 Finish

This finish is for surfaces which are permanently exposed to view but the highest standard of finish is not required. Forms to provide a Class F2 finish shall be faced with wrought thicknesses tongued and grooved boards with square edges arranged in uniform pattern and close jointed or with suitable sheet material. The thickness of boards or sheets shall be such that there shall be no visible deflection under the pressure exerted by the concrete placed against them.

Joints between boards or panels shall be horizontal and vertical unless otherwise directed. In this type of finish pitting, fins surface discoloration and other minor defects shall be remedied at the time and by methods agreed by the Engineer.

(c) Class F3 Finish

This is for surfaces which will be in contact with water flowing at high velocity, and for surfaces prominently exposed to view where good appearance is of special importance. To achieve this finish, which shall be free of board marks, the formwork shall be faced with plywood or equivalent material in large sheets. The sheets shall be arranged in an approved uniform pattern. Wherever possible, joints between sheets shall be arranged to coincide with architectural features or changes in direction of the surfaces.

All joints between panels shall be vertical and horizontal unless otherwise directed. Suitable joints shall be provided between sheets to maintain accurate alignment in the plane of the sheets. Unfaced wrought boarding or standard steel panels will not be permitted for Class F3 finish. The Contractor shall ensure that the surface is protected from rust marks, spillages and stains of all kinds.

(d) Curved Surfaces

For curved surfaces where F2 or F3 finishes are called for, the formwork face shall be built up of splines cut to make a tight surface which shall then be dressed to produce the required finish.

Alternatively, single curvature surfaces may be faced with plastic or plywood linings attached to the backing with adhesive or with escutcheon pins driven flush. Linings shall not bulge, wrinkle or otherwise deform when subjected to temperature and moisture changes.

(e) Tolerances

All parts of formed concrete surfaces shall be in the positions shown on the Drawing within the tolerances set out in Table 9.2.

In cases where the Drawing call for tolerances other than those given in Table 9.2 the Drawing shall rule.

Where precast units have been set to a specified tolerance, further adjustments shall be made as necessary to produce a satisfactory straight or curved line. When the Engineer has approved the alignment, the Contractor shall fix the units so that there is no possibility of further movement.

Table 9.2: Tolerances

Class of finish	Tolerances in mm (See Note)		
	A	B	C
F1	10	10	+25 to – 10
F2	5	10	±15
F3	2	5	±10

***Note**: The tolerances A, B and C given in the table are defined as follows:*

A Is an abrupt irregularity in the surface due to misaligned formwork or defects in the face of the formwork

B Is gradual deviation from a plane surface as indicated by a straight edge 3 m long. In the case of curved surfaces, the straight edge shall be replaced by a correctly shaped template.

C Is the amount by which the whole or part of a concrete face is displaced form the correct positions shown on the Drawing

906 FINISHES ON UNFORMED SURFACES

Horizontal or nearly horizontal surfaces which are not cast against formwork shall be finished to the class shown on the Drawing and defined hereunder.

(1) UF 1 Finish

All surfaces on which no higher class of finish called for on the Drawing or instructed by the Engineer shall be given a UF 1 finish.

The concrete shall be levelled and screeded to produce a uniform plain or ridged surface, surplus concrete being struck off by a straight edge immediately after compaction.

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(2) UF 2 Finish

This is a floated finish for roof or floor slabs and other surfaces where a hard trawled surface is not required. The surface shall first be treated as a class UF 1 finish and after the concrete has or machine sufficient only to produce a uniform surface free from screed marks.

(3) UF 3 Finish

This is a hard trowel led surface for use where weather resistance or appearance is important, or which is subject to high velocity water flow.

The surface shall be floated as for a UF 2 finish but to the tolerance stated below in Sub-clause 906 (5). When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, it shall be steel-trowel led under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

(4) Finishing of Hydraulic and Structural Concrete Surfaces

Concrete surfaces forming canal beds, aqueduct floors, stilling basins, chutes, transitions, energy dissipators, spillways and other hydraulic surfaces shall be finished to the lines, levels, slopes and tolerances shown on the drawings.

Where the surface is intended to carry water at high velocity, the finish shall be smooth, dense and uniform and shall comply with the requirements for UF3 finish unless otherwise specified.

The placing the concrete in hydraulic and structural surfaces shall not be permitted until the Engineer is satisfied that appropriate methods, equipment such as concrete finishers and experienced operator, are employed to finish the structures, and all necessary finishing tools and equipment are available on site and in satisfactory conditions for use.

There should not be any irregularities, ridges, depressions, projections and other surface defects that could adversely affect hydraulic performance.

(5) Tolerances

All parts of unformed concrete surfaces shall be in the positions shown on the Drawing within the tolerances set out in Table 9.3.

In case where the Drawing call for tolerances other than those given in Table 9.3 the Drawing shall rule.

Table 9.3: Tolerances

Class of finish	**Tolerances in mm (See Note)**		
	A	B	C
UF1	Not applicable	10	+20 to – 10
UF2	Nil	10	+20 or – 10
UF3	Nil	5	+12.5 or – 7.5

***Note**: The tolerances A, B and C given in the table are defined as follows:*

A is the maximum allowable value of any sudden change of level in the surface.

B is the maximum allowable value of any gradual irregularity of the surface, as indicated by the gap between the surface and a three-meter-long straight edge or correctly shaped template place on the surface.

C is the maximum allowable value of the in level or position between a three- meter-long straightedge

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or correctly shaped template placed on the surface and the specified level or position of that surface.

907 REMEDIAL WORK TO DEFECTIVE SURFACES

If no removal of any formwork the concrete surface is found to be defective in any way, the Contractor shall make no attempt to remedy such defects prior to the Engineer's inspection and the receipt of any instructions which the Engineer may give Defective surfaces shall not be made good by plastering.

Areas of honey combing which the Engineer agrees, shall be repaired after cutting back to sound concrete when the concrete is no more than 3 days old. Care shall be taken that reinforcement and sheathing ducts are not damaged. The cavity shall have sides at right angles to the face of the concrete. After cleaning out with water and compressed air, a thin layer of cement grout shall be brushed on to the concrete surfaces in the cavity. It shall then be filled immediately with the concrete of the same class as the main body. The concrete shall be prepared from the aggregate of maximum size 0.5 times the depth of the cavity or 20 mm whichever is the smaller. A form provided with a lip to enable concrete to be placed shall be used against the cavity. The form shall be filled above the top edge of the cavity.

After seven days the lip of concrete shall be broken off and the surface shall be ground smooth. When the concrete is more than three days old, areas of honey combing shall be repaired using an epoxy bonding agent with a method approved by the Engineer.

Surface irregularities which are outside the limits of tolerance set out in Clause 906 shall be ground down in the manner and to the extent instructed by the Engineer.

Blowholes in vertical surfaces shall be filled with laitance, or mortar using fine aggregate not larger than 0.3 mm, rubbed over the affected area with a rubber face float and finished with polythene.

Defects other than those mentioned above shall be dealt with as instructed by the Engineer.

908 MEASUREMENT

Unless stated otherwise, the formwork for concrete in Plain Concrete or Reinforced Concrete or Pre-stressed Concrete shall be measured for payment in square meter of the surface area of concrete which is in contact with formwork in accordance with this Section. Similarly, Falsework shall be measured in square meter for payment.

909 PAYMENT

The formwork and false work specifically provided as a separate item, shall be paid as per the contract unit rate. The Contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

SECTION 1000: ROOFWORK

1001 SCOPE OF WORK 10-1

1002 GENERAL..... 10-1

1003 MATERIALS 10-1

1004 MEASUREMENT 10-4

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1001 SCOPE OF WORK

This Section covers the construction of roof using different materials such as CGI Sheet, GI sheet, Corrugated Fiber Glass sheet, Corrugated asbestos cement sheet, Slate, Thatch Roof, Lime concrete (1:1:3) etc. and other roofing arrangements as required.

1002 GENERAL

The Contractor shall be responsible for construction of different roofs shown on the Drawing in accordance with this Section and other relevant Section of these Specification. Before construction begins, the Contractor shall submit to the Engineer Drawing showing details of the proposed roof work as the case may be.

1003 MATERIALS

(1) CGI ROOFING SHEET

The CGI roofing sheet may be plain or colored as shown in the drawing. The surfaces of the sheets must be clean, bright and free from rust; any sheet showing a white powdery substance shall not be entertained. The material for CGI roof sheets (Iron) shall be galvanized after the process of corrugation. Engineer shall not accept Iron (used for CGI sheet) galvanization before the process of corrugations. The thickness of CGI sheet shall not be less than 0.63mm as specified in IS code 12093 and plain GI ridge of approved brand and color shall be used.

(a) Laying and Fixing

CGI Sheets are laid over purlins, one at each end and one in the middle of each sheet. Each sheet is laid with end lap of 150 mm, and the side lap should be of 2 corrugations. The sheets are either riveted or jointed with limpet washer. The rivet holes should be drilled & all holes should be in ridges and never in gutters. The tools must be very sharp so that there is no tearing. It is better to rivet 3 or 4 in breadth and then hoisted to the position. The rivet holes should be about 224 mm apart on the sides and at every second corrugation at the ends where four sheets overlap. It is better to drill the holes do not punch.

All rivets will be G.I. and will be passed from below with a lead washer on the top extending 12 mm round beyond the edge of the hole. Care should be taken that the sheet is well supported underneath and no inundations are made on the upper surface. The sheets are secured to the iron purlins by means of 10 mm dia. hooks or bolts passing through the sheets and 75 mm screws to the wooden purlins. The bolt holes should be slightly larger than the diameter of the bolts and covered with a limpet or leaden washer. All rivets, bolts etc. should be set in white lead.

(b) Ridge and Hips

The ridges and hips are covered by plain G.I. riveted sheets and fastened with limpet washers to Plain GI sheets and overlap of 300 mm on each side and joint set in white lead.

The sheets should be fastened at eaves and ends, by continuous length of flat steel bars called "Wind Ties" which are usually 40 mm x 6 mm with slotted holes bolted down to the bressummer or rafter at about 100 mm intervals. These bolts should not be less than 45 mm in length with 150 mm square plates over pillars or walls. The projection at eaves is generally 32 mm to 50 mm.

The pitch is sloped up to 25 to 40 degrees. The finished surface shall be uniform, and the lines of corrugations shall be uniform and the lines of corrugations shall be straight and parallel.

(2) Corrugated Fiber Glass Sheet

Corrugated fiberglass sheets, commonly used for roofing, are made from fiberglass reinforced with polyester resin, which makes them resistant to corrosion and various weather conditions. They are used for roofing because of their lightweight, durability, UV Resistance, versatility, cost-effective nature, ease of installation and fire resistance property. It's worth noting that while corrugated fiberglass sheets offer many advantages, they may have some limitations as well. For instance, they may not be as insulating as other roofing materials, such as metal or foam panels. Additionally, proper installation techniques and

maintenance are crucial to ensure their long-term performance.

The material shall be composed of a thermosetting styrenated or acrylated polyester resin system reinforced with glassfibre. The glassfibre used as reinforcement shall be in the form of chopped strand mat having a highly soluble modified polyester binder in accordance with IS 11551: 1986 having a density of 450 g/m^2 and minimum width of 500 mm.

The sheets shall have a smooth surface finish on both sides. The thickness of the sheet shall be 1.1mm with tolerance of 0.15mm when measured with thickness gauge. The thickness shall be measured at least at 10 random points on all the four Sides, and the average value shall be taken (IS 12866:1989).

The glass content in the laminate shall not be less than 30 percent of its original weight. The sheets shall not absorb water in excess of 0.3 percent of its weight. When the sheets are tested for its hardness, the Barcol hardness shall not increase by more than 30 percent of its initial value (IS 12866:1989).

(3) Slate Roofing

Slates are widely used for roofing work. They are rectangular in shape with uniform thickness. The specific advantage of these roofs is the ease of maintenance, since any broken slate may be easily replaced without much disturbance to the roofing as a whole. Generally slates of sizes, 60 x 30 cm, 50 x 25 cm and 40 x 20 cm and of thickness not less than 15 mm, shall be used for roofing.

The slate for roofing shall be free from veins, cracks, or other similar source of weakness. They shall be of uniform colour and texture and shall not contain white patches and deleterious minerals. The slate shall be of reasonably straight cleavage and the grains shall be longitudinal. The slates shall be hard and brittle but not tough. When struck, it shall give ringing sound and shall not break when it is let fall flat on hard ground from a height of 1.25 metres. The surface of the slates shall be such as to permit proper laying of the slates. The slates shall be impervious to moisture. The percentage absorption by weight of the slate after it is kept immersed in water for a period of six hours shall not be more than 2 percent of its weight before immersion. When the slate is kept dipped on edge in water for six hours, the water level shall not rise to more than 12 mm and the immerse & edge shall not show signs of swelling, splitting, or flaking.

(4) Clay Tile Roofing

The terracing clay tile shall be made from good soil of even texture and shall be uniformly well burnt. They shall be uniform in shape and sizes and shall be free from irregularities, such as twists, bends, cracks and particles of stones. The Clay tiles are found in different dimensions. The tolerances in length, width and thickness shall be of ± 3 percent. The maximum warpage for the tiles measured shall not exceed 2 percent of the dimensions in any direction. The water absorption by weight when tested according to the method described in IS 3495 (Part 2): 1992 shall not exceed 20 percent. The modulus of rupture in bending when tested as per IS 2690 (Part 2): 1992, shall not be less than 1.5 N/mm^2.

(5) Cement Concrete Tile

Cement Concrete tiles are intended for use as roof covering where durability and appearance are required to provide a weather-resistant surface of specified design. The tiles are manufactured from Portland cement, water, and mineral aggregates and shaped during manufacturing by molding, pressing, or extrusion. Tiles are generally planar or undulating rectangular shapes available in a variety of cross-sectional areas profiles, shapes, sizes, surface textures, and colors. Cement concrete tiles are laid over roofs in 1:4 Cement Sand mortar.

Additionally, proper surface preparation, including cleaning and priming the roof substrate, is essential for ensuring a strong bond between the mortar and the tiles. Adequate curing time for the mortar is also necessary to achieve optimal strength and stability.

(6) UPVC Sheets for Roofing

UPVC Sheets are intended for use as roof covering due to its integral properties as heat and sound insulation, fire retardant, chemical resistance, non-corrosive, water proof, high strength, eco-friendly, etc. It is available in various sizes and colors with varying thickness ranging from 1mm to 3mm. UPVC sheets

manufactured using materials such as PVC Resin, Stabilizers, Impact Modifiers, UV Stabilizers, Pigments and Colorant, Fillers, etc. are processed and mixed together using extrusion or calendaring techniques to form the UPVC sheets with the desired thickness, surface finish, and other characteristics. The finished products of UPVC sheets shall be examined to verify the composition and compliance with applicable regulations to ensure the safety, quality, and environmental sustainability of the product before use.

UPVC sheets shall have a smooth surface finish on both sides. The thickness of the sheet shall be 2 mm or 3 mm as required with tolerance of 0.15mm when measured with thickness gauge. The thickness shall be measured at least at 10 random points on all the four Sides and the average value shall be taken (IS 12866:1989). The sheets shall not absorb water in excess of 0.3 percent of its weight and density of sheet shall not be less than 1.43g/cm^3.

(7) Lime Concreting for Terraced Roof

Lime Concreting for terraced roof shall be of 10 cm thick in 1:1:3 (lime Surkhi brick aggregate). Lime, Surkhi, Brick Aggregate and water shall be as per this specification and other relevant specification under this specification.

(8) Thatched Roof

The thatch roof is generally mounted on mud wall keeping a slope of 30°. The bamboo frame is prepared by approximately 50 mm diameter sticks, placed across each other about 300 mm apart and tied with babiyo ropes or any other thin strong string, or nailed. The Bamboo mat if required, is laid over the bamboo frame. The bundle of rice paddy straw shall be laid and fixed on the frame as close as possible in such a way that a required thickness of 8 cm or 15 cm of the thatch may be obtained. The thatch shall be projected at least 300 to 450 mm outside the mud wall or supporting structure.

(9) GI Rain Water Gutter

Rain Water gutter shall be made of plain or colored GI sheet having width ranging from 150mm to 450mm as required and shall be fitted to rain water pipe using required accessories. The surfaces of the sheets must be clean, bright and free from rust and sheet showing a white powdery deposit should not be used. The GI Sheet to be used as rain water gutter shall be galvanized after the process of corrugation.

(10) Wood works for Ceiling, Main Beam, Cross Beam and Truss

Wooden Ceiling, Main Beam, Cross Beam and Wooden Truss shall be made of sal wood and shall be as per this specification and other relevant specifications under this specification.

(11) Eaves-board

The eaves board, also known as the fascia board, is typically installed horizontally along the lower edge of the roof to provide a smooth and finished appearance to the roofline. It also helps protect the underlying roof structure and aids in directing water away from the building. Eaves boards shall be 25mm thick and made of sal wood and fixed to the roof using quality nails. The material used for eaves board shall be as per this specification and other relevant specifications under this specification.

(12) False Ceiling Using Sal Wood Frame and Commercial Plywood

Where specified in the Drawings, false ceiling shall be constructed using a sal wood frame and commercial plywood. The sal wood framing shall be properly seasoned, straight and sound and shall be securely fixed to the supporting structure.

Unless otherwise specified, the framing shall comprise sal wood members of size 50 mm × 75 mm or as shown in the Drawings.

The ceiling shall be finished with either 3 mm commercial plywood or 12 mm hardboard, properly cut, aligned and securely fixed to the wooden frame. Beads, nails, screws and other necessary fixing accessories shall be provided as required.

All joints shall be properly aligned and finished. The completed false ceiling shall be level, uniform and free from sagging, warping, cracks and other visible defects.

1004 MEASUREMENT

Unless stated otherwise, the CGI sheet roofing shall be measured in Sqm. and plain GI sheet ridge in Rm. Corrugated Fiber Glass Sheet shall be measured in Sqm and Fiber Glass ridge in Rm. Slate roofing shall be measured in Sqm. Clay tile roofing shall be measured in Sqm and Clay tile ridge shall be measured in Rm. Cement Concrete Tile shall be measured in Sqm. UPVC Sheet shall be measured in Sqm. Lime Concreting for Terraced Roof, whose thickness is 10cm shall be measured in Sqm. Thatched Roof of required thickness shall be measured in Sqm. GI Rain Water Gutter of specified width shall be measured in Rm. Wooden Ceiling shall be measured in Sqm whereas Main Beam, Cross Beam and Wooden Truss shall be measured in Cum. Eaves-board of required thickness (25mm) shall be measured in Sqm. False ceiling (thickness specified) shall be measured in Sqm.

1005 PAYMENT

The CGI Sheet and GI sheet ridge, Corrugated Fiber Glass Sheet and Fiber Glass ridge, Slate Roofing, Clay Tile roofing and Ridge, Cement Concrete Tile, UPVC Sheets, Lime Concreting for Terraced Roof, Thatched Roof, GI Rain Water Gutter, Wooden Ceiling, Main Beam, Cross Beam, Wooden Truss and Sal Wood Eaves-board shall be paid as per the contract unit rate. The Contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

SECTION 1100 –TIMBER, DOORS AND WINDOWS WORKS

1101 SCOPE 11-1

1102 MATERIALS 11-1

1103 CONSTRUCTION 11-3

1104 TESTS AND STANDARDS OF ACCEPTANCE 11-3

1105 MEASUREMNT 11-3

1106 PAYMENT 11-3

1101 SCOPE

This Section covers timber construction and doors and windows works at locations as shown in the Drawing. The woodwork specified herein may not be relevant for the temporary facilities like formworks (centering and shuttering).

1102 MATERIALS

(1) Timber

Timber (sal wood) used for timber construction, doors and windows works shall be straight and free form twist, sapwood, shakes, dead and loose knots, worm holes, other holes, signs of decay and other defects, and seasoned and shall comply with the requirements of IS: 883 The Engineer shall inspect and stamp each timber to be used as structural members. The natural moisture content of any untreated timber delivered to site shall not exceed those as recommended by IS: 287. When timber is specified as unsawn it shall be cut above the ground swell and shall taper from butt to tip. A straight line drawn from the centre of the tip to the centre of the butt shall not fall outside the centre line of the piece at any point more than 1% of the length of the piece. When the timber is specified as sawn it shall be sawn true and square to the full dimensions. When timber is specified as sawn it shall be finished with a plane, smooth and true to dimensions on the faces so specified.

Timber species (sal wood) for the manufacture of specified door and window shutters shall have adequate strength, weight, retention of shape, ease of working, finish smooth and shall be sufficiently durable and/or treatable and shall have excellent appearance and figure and show good gloss after polishing. Timber species (sal wood) for the manufacture of specified door and window frames shall have adequate strength, weight, retention of shape, finish smooth and shall be sufficiently durable and/or treatable.

(2) Hardware

Hardware used for timber construction, doors and windows shall consist of bolts, with the necessary nuts and washers, timber connectors, drift pins, dowels, nails, screw nails, coach bolts, spikes, handles, holdfast, hinge, different lock, spring and other metal fasteners. They shall be galvanized or ungalvanized as specified. Bolts, nuts and washers shall be mild steel and comply with IS: 1363. Timber connector shall be of the type shown on the Drawing. Drift Pins and dowels shall be mild steel. Nails shall comply with IS: 723. Screw nails and screws shall comply with IS: 451/IS: 2585. Coach bolts shall comply with IS: 2609. Spikes, handles, holdfast, hinge, spring, different locks and other metal fastenings shall be of mild steel.

(3) Timber Preservation

When described in the contract or shown on the Drawing timber shall be treated with preservative in accordance with the Indian Standard Code of Practice for the preservation of timber IS: 401.

(4) Galvanizing

When described in the contract or shown on the Drawing, all hardware shall be galvanized in accordance with the Indian Standard Recommended Practice for Hot-Dip Galvanizing or Iron and Steel: IS: 2629 and IS: 1367 Part 13: Hot Dip Galvanized Coating on threaded Fasteners. The Engineer may require galvanized hardware to be tested in accordance with IS: 2633.

(5) Plywood

Plywood shall be commercial or teak plywood as specified in contract or shown on the drawing. The faces of the plywood panels shall be smooth with uniform thickness within the tolerance limit of ± 10%. The moisture content of one test piece cut from each panel when determined as per IS 1734 (Part 1) shall not be less than 5 % and not more than 15 %. Plywood shall have adequate tensile strength and resistance to microorganisms.

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(6) Sunmica / Formica

Sunmica/Formica or laminate which is made by layering multiple sheets of resin-impregnated kraft paper together bonded under high heat and pressure shall be used for making shutters as specified in the contract or on the drawing. Its top layer shall be typically a decorative paper with various patterns, colors, and textures, while the bottom layers provide strength and stability. Sunmica and Formica to be used shall have adequate resistance to surface wear and surface blow.

(7) Mosquito-proof GI wire mesh

Mosquito-proof GI wire mesh shall be of minimum 20 mesh per square inch, made of galvanized iron wire of 24 gauge. The mesh shall be free from defects, properly tensioned and securely fixed to the frame with seasoned timber beads or steel plates as shown on the Drawings or specified in the Contract.

(8) Glasses for Doors and Windows

Glasses of various thickness as specified in contract or on drawing shall be used for Doors, Shutters and Windows Frames. Glasses to be used for doors and windows shall be Heat strengthened glass having the surface compressive stress to be greater than 24 MPa but less than 52 MPa and Ultimate design strength ($\boldsymbol{py}$) under short-term load duration shall not be less than 40 MPa. Its temperature resistivity should not be less than 100° Celsius.

(9) Aluminum Doors and Window frames and shutters

Aluminum Doors and Windows frames and shutters shall be fabricated in different sizes as specified in contract and on the drawings. Extruded aluminum components shall be manufactured from aluminum alloy B 6063 - T5. The lining to louver panels shall be 1.0 mm thick sheet aluminum powdered as specified. Hardware and hinges shall be as approved by the Engineer. Aluminum work shall be fabricated in accordance with the prevalent practice among the local Manufacturers and as per drawings showing jointing details, hardware and extrusion profiles. Contractor shall be liable to ensure that all fabricated aluminum work is carried out in accordance with contract and the drawings.

A thick layer of clear, transparent lacquer based on methacrylates or cellulose butyrate, shall be applied on aluminum doors, windows by the suppliers/contractors to protect the surface from wet cement during installation. This lacquer coating shall be removed after installation is completed.

The sizes for door, Window or ventilator frames shall not vary by more than ± 1·5 mm as per IS code: 1948-1961. Main members shall be of such strength that a wind pressure of 1.16 kPa shall cause a deflection of not more than 1/240 of the span of the member.

No permanent deflection shall result from such conditions of loading. Fixing to members shall be such that the above loading shall be generated in the members without sufficient stress to cause failure or movement to be evident at any joint. The Contractor shall take full responsibility that all fabricated aluminium work shall comply with the above conditions. Load bearing brackets shall be manufactured from 40 x 6 mm. mild steel bent to shape, hot dipped galvanized, bitumen coated only on surfaces coming in contact with aluminium and spaced at not more than 500 mm centers. Load bearing brackets shall be fabricated and fixed as per drawings and direction of Engineer.

Vertical and horizontal expansion joints shall be so designed as to cover all weather conditions likely to be encountered on the site. All flashing required to be built in as the work proceeds shall be supplied by the contractor and built in by the trade concerned. All other flashing as detailed on the drawings shall be supplied and fixed in position contractor. The aluminium door, window, frames shall be installed in position and fixed rigidly in the wall, columns with metal grips confirming ISI and stainless steel screws of dia. 6 - 8 mm. The spacing of grips shall be kept at 600mm. Approved British weather piles seals shall be metal backed, siliconized, of the required size called for.

(10) Others

The material used for other works like GI Flush Shutter, Mosquito proof GI net, Steel bar in window frame,

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etc. shall be as per this specification and other relevant specification under this specification.

1103 CONSTRUCTION OF TIMBER WORKS

(1) Handling and Storage of Materials

Timber shall be stored in piles at the site unless it is to be immediately incorporated in the structure. It shall be stacked so as to allow free air circulation and inspection on skids above the ground and standing water. It shall be protected from the sun to prevent warping. It shall be handled in a manner that will avoid injury or breakage. Treated timber shall be handled with rope slings. Cant hooks or other sharp instruments shall not be used. Undue injury during handling will be cause for rejection. Flashing, hardware, preservatives and other material shall be stored under cover in such a manner as to obviate deterioration.

(2) Framing

All timber shall be accurately cut and framed to a close fit and shall have even bearing over the entire contact surfaces. No shimming shall be permitted in making joints. Holes for drift pins and dowels in untreated timber shall be bored with a bit 1.5 mm less in diameter than the pin or dowel. Holes for drift pins and dowels in treated timber shall be bored to the same diameter as the pin or dowel. Holes in small timbers for spikes may be bored with a bit with the same diameter as the smaller end of the spike, when necessary to prevent splitting. All bolts shall be fitted with washers. Ground sills shall be firmly and evenly bedded in solid material. Posts shall be framed true and have full even bearing on the sills, caps shall be framed true and have full bearing on the posts or piles. Bents shall be properly aligned before bracing is placed. The minimum distance between the outside bolt and the end of any brace shall be 200 mm.

The top of beams and stringers after placing shall not vary from a plane more than that will permit bearing of the timber on all the beams and/or stringers. Edges and finishing members shall be accurately framed and aligned so that on completion they present a smooth visual line vertically and horizontally. Floor planks shall be laid such that no joints will occur over any one stringer or beam closer than every third plank. No planks other than required to fill out irregularities shall be less than 2 metres in length and at least 50% of the planks shall be 5 metres or more in length. Close boarded floor planks shall be laid longitudinally breaking joint by at least 600 mm. They shall be secured in place by barbed nails, screws or coach bolts as shown on the Drawing, or described in the contract. These fastenings shall be spaced at not more than 250 mm and be staggered. Two fasteners shall be placed at each end of each plank.

1104 TESTS AND STANDARDS OF ACCEPTANCE

The materials shall be tested in accordance with the relevant standards specified and shall meet the prescribed criteria. The Contractor shall furnish necessary test certificates as required by the Engineer

The work shall conform to these Specifications and shall be to the true lines, levels and dimensions as indicated on the Drawing or as directed by the Engineer.

1105 MEASUREMNT

Depending upon the nature of work, the quantities of different works shall be measured in numbers, in the units of weight or volume or area or length as specified in the contract.

1106 PAYMENT

The quantities of different works measured shall be paid at the contract unit rate applicable for the particular type of work. The Contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

SECTION 1200: FLOORING WORK

1201 SCOPE OF WORK 12-1

1202 GENERAL 12-1

1203 MATERIALS 12-1

1204 MEASUREMENT 12-7

1205 PAYMENT 12-7

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1201 SCOPE OF WORK

This Section covers the construction and finishing of flooring using different materials such as Cement Concrete, Cement Plaster, Mosaic (Marble Chips and White Cement), Terrazzo Tiles, Marble, Porcelain Glazed Tile, Flagstone, Flat stone, Dense (Teliya) Brick, Brick, Parquet, Stone, Timber, Granite, Interlocking Concrete Block, Clay Tile, Anti slip Cement Tile, Glazed Ceramics Tile, Glazed and Non-Glazed Tile, Vitrified Tile, Anti Acid/Alkali Tile, PVC Tile, etc. and other flooring arrangements as required.

1202 GENERAL

The Contractor shall be responsible for construction of different floors shown on the Drawing in accordance with this Section and other relevant Section of this Specification. Before construction begins, the Contractor shall submit to the Engineer Drawing showing details of the proposed flooring work as the case may be.

1203 MATERIALS

(1) Cement Concrete

Preparation of Base

Before laying the cement concrete, base shall be cleared of all loose earth, rubbish and other foreign matter. If necessary, the base shall be packed and chipped and cleaned with wire brushes. Clean base shall then be wetted with water thoroughly, but no water pool shall be allowed. Necessary slope shall be given in base itself.

Proportion

The proportion of cement concrete shall be 1 cement: 2 sand: 4 stone aggregate 20 mm. and down by volume as specified in the schedule. Grading of aggregate shall be as per reinforced concrete specification.

Placing

The floors shall be laid to specify thickness in panels of uniform size not exceeding 1.5 sq. m. (one side not exceeding 1.5 m) these shall be laid in alternate panels on different days if no glass stripes are provided. The edge of the panels shall be protected by flat bars of iron or wood, their depth equal to that of flooring. When glass strips are provided all the panels of the flooring can be cast in one operation.

Finishing

The concrete laid shall be compacted first with wood float. The blows shall be fairly heavy but as consolidation takes place, light rapid strokes shall be given. Beating shall continue till all hollows in concrete are filled with mortar cream. Then the surface shall be trowelled till the moisture disappears. The surface shall be checked with straight edge. The finish surface shall be cured for 7 days. Sample of workmanship shall be got approved prior to work.

(2) Terrazzo Tiles/ Mosaic Flooring

The aggregates used in terrazzo topping shall be marble aggregates size varying from 1 mm to 25 mm, Marble powder used in terrazzo topping shall pass through sieve 300 conforming to IS: 460 (Part I)-2020. Aggregates for terrazzo under layer as well as the base concrete shall conform to the requirements of IS: 383-2016. Cement used shall conform to IS: 269-2015. White Cement used shall conform to IS: 8042-2015. The pigments used shall be of the permanent colour. The material for dividing strip shall be such that it has resistance for flooring. The dividing strip may be aluminium, copper, grass, or similar material. The thickness shall not be less than 1.5mm and width less than 25mm.

The base of the mosaic flooring shall be cement concrete (1:2:4) or Cement concrete plaster (1:2) or Cement plaster (1:2) of different thickness as specified in contract or on the drawing. The surface course over base course shall be of White cement and marble chips in 1:1 ratio having different thickness as specified in the contract or on the drawing. The base shall be made rough, watered and given a cement wash and then the base course (concrete or concrete plaster or plaster) shall be laid in required thickness in panels as instructed by the Engineer. Panels shall be bound by glass strips 6 mm thick and 25 mm wide,

after laying the concrete shall be compacted and levelled by beating and tamping with wooden floats. Proper slope for draining wash water shall be provided as per the instructions of the Engineer. Within two hours of laying of the base course of cement concrete, the upper course of white/colored cement, marble dust and marble chips shall be laid with straight edge flat and trowel. Additional marble chips may be spread on the finished surface and tamped and compacted properly so that final surface is covered with chips to the extent of 70% to 80% of the exposed area.

After about two hours of laying, the surface shall be covered with wet sacks and kept wet and left undisturbed for at least two days.

Finish

The surface shall be ground by rubbing with mechanical grinders, hand grinders where mechanical; grinders cannot reach and all the cement in surface removed. A neat cement wash shall then be given on the surface and left undisturbed for six days and then the surface shall be ground mechanically with carborundum stones of different grades starting with course ones and successively finishing with fine ones and rubbing shall be continued until the entire surface shows a uniform granular appearance. The surface shall be kept wet during all these days. After final grinding the surface shall be thoroughly cleaned by washing with soft soap water and then with clean water.

Finally, when the surface is absolutely dry, oxalic acid powder shall be rubbed well on the surface with a piece of wet felt and this operation shall be repeated until the surface becomes perfectly smooth and glossy. Then the surface shall be rubbed with wax polish to give a glazing surface. White or colored cement shall be used as approved by the Engineer.

(3) Marble

Marble stone floor shall be used for specified areas. The marble slabs shall be of selected quality, hard, sound, dense, and homogeneous in texture free from cracks, decay, weathering and flaws as approved by the Engineer. The specific gravity shall be minimum of 2.5 and minimum hardness of 3 and moisture absorption of maximum 0.4% by weight.

The thickness of the marble slab shall be 15 mm and shall be machine cut to required dimensions. The bedding mortar for the marble slab shall be minimum 20 mm thick 1:2 (1 cement: 2 sand mortar) or 20 mm thick 1:2 (1 Lime:2 Surkhi mortar) as specified in the contract or on the drawing. Before laying marble floor it is essential that a level surface is required. The joints shall be as fine as possible. The flooring shall be cured for a minimum period of seven days. Slight unevenness at the meeting of edges of marble slabs shall be removed by chiselling. The surface shall be ground evenly with machine fitted with finest grade grinding stones. Then oxalic acid shall be dusted over the surface sprinkled with water and rubbed hard with pad and woollen rags to give smooth and shining finished surface.

(4) Porcelain Glazed Tile

Materials

Mat finish porcelain tiles shall be of homogeneous natural finish of approved colour, model and make. These shall be of specified size as specified in the contract or on the drawing and approved by the Engineer.

Installing the Tile

Prior to installing any tile, the Contractor shall inspect surfaces and conditions in areas to receive tile work and shall notify the Engineer of any serious defects or conditions that will interfere with or prevent a satisfactory tile installation.

The surface shall be brushed, cleaned and wetted. Tile shall be soaked completely by immersing in clean water at least 30 minutes and drained. No free moisture shall be allowed to remain on the backs of the tiles at the time of setting. Tiles shall be installed by applying cement sand plaster of 1:4 (1 cement: 4 sand), cement sand mortar maximum 12 mm thick on wall/floor by firmly pressing tile into the cement mortar applied on the wall so that the back of the tile is completely in touch with the mortar. Joints in the

tile work shall be accurately aligned with horizontal joints level and vertical joints in plumb. Joints shall be maintained uniformly 1.5 mm wide or as directed by the Engineer by aligning spacer lugs on tile edges if tiles are so manufactured or by use of wetted strings. Tiles shall be laid out in such a way that no tile is less than half size course. Where tile must be cut at edges or penetrated the cut edges shall be carefully filed and neatly ground. Chipped, cracked or broken tiles shall not be used and all defective work shall be replaced and repaired to the satisfaction of the Engineer at the Contractor's expense.

After tiles have been set firm and strings from set tiles removed, tiles shall be dampened and joints grouted full with a plastic mix of white cement by trowel, brush or finger application. During grouting all excess grout shall be cleaned off the tile surface with damp cloth or sponge. All tile work finishing shall be adequately protected from damage during the progress of construction till completion and any damage shall be repaired to the satisfaction of the Engineer at the Contractor's expense. Upon completion prior to final inspection and acceptance, the Contractor shall clean all tile work. Acids or other agents liable to damage the work shall be avoided. If tile surface shows mass scratches, cracks or other imperfections, which cannot be removed by cleaning; the contractor shall remove the defective material and replace with new material at no additional expense. Sample of workmanship shall be approved prior to execution of work.

(5) Flagstone /Flatstone

Flagstone/Flatstone shall be of specified size as specified in the contract or on the drawing and approved by the Engineer. The surface shall be brushed, cleaned and wetted. Flagstones shall be soaked completely by immersing in clean water at least 20 minutes and drained. No free moisture shall be allowed to remain on the backs of the flagstones at the time of setting. These stones shall be laid on cement sand mortar (1:4) base, thickness not less than 20mm or sand base thickness not less than 15 cm. Sample of workmanship shall be approved prior to execution of work.

When the stone slabs are properly set, mortar in the joints is raked out to a depth of about 20 mm. and flush pointed with cement mortar (1:3). A slope of 1 to 40 is necessary to be given in flag stone flooring for proper drainage.

(6) Dense (Teliya) Brick

The flooring with dense (Teliya) bricks shall conform to IS: 1077-2025 for light duty floors and IS: 2180-1988 for heavy duty floors. The fine aggregate shall conform to IS: 383-2016. Cement shall be conformed to IS: 269-2015. Lime shall conform to IS 2541 and lime mortar for bedding and joints shall conform to IS: 1625-1981.

The delivery of bricks shall be so arranged as to minimize handling and adequate precaution shall be taken- to prevent damage to bricks while unloading. Clean dry space shall be provided at the site for the storage of all materials. Cement and lime shall be stored under cover. The materials shall be stored in accordance with IS: 4082-1996.

Lime Surkhi mortar, not less than 10 mm thick shall be spread evenly over the base concrete. The bricks before being laid shall be soaked in clean water and then allowed to drain until they are surface dry. The Teliya bricks (25mm thick) shall be laid in plain, diagonal, herringbone or other suitable patterns. The bricks shall be laid flat and set by gentle tapping with handle of trowel or wooden mallet. The thickness of the joints shall be between 8 to 10 mm. The joints shall be flush pointed with 1:1 cement sand mortar after being raked out 10 mm deep while the mortar is still green. On completion of a portion of flooring, the vertical joints shall be fully filled with mortar from the top. The flooring shall be kept wet (curing) for at least 7 days after completion.

(7) Brick Flooring

The flooring with burnt clay bricks on edge or flat shall conform to IS: 1077-2025for light duty floors. The fine aggregate shall conform to IS: 383-2016 and Cement shall be conformed to IS: 269-2015. The bricks on edge shall be laid on 1:6 Cement sand mortar and joints shall be flush pointed with 1:2 cement sand mortar. For flat bricks flooring, bricks shall be laid in dry mixture of cement sand with nominal cement and joints shall be pointed with 1:2 Cement sand mortar. The thickness of dry cement sand base shall not be

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less than 10 cm.

Bricks shall be stored at working site in clean dry space with due care to minimize/ prevent damage to bricks while unloading. Cement and sand shall be stored under cover in accordance with IS: 4082-1996.

Dry mix of cement sand or cement sand mortar as the case maybe shall be spread evenly over the base floor area. The bricks before being laid shall be soaked in clean water and then allowed to drain until they are surface dry. The bricks laid flat or on edge shall be allowed to set by gentle tapping with handle of trowel or wooden mallet. The joints (8 to 10 mm thick) shall be flush pointed after being raked out 10 mm deep while the mortar is still green. The flooring shall be kept wet (curing) for at least 7 days after completion.

(8) Parquet Flooring

Materials

Timber to be used for parquet flooring shall be Sal or Sesham, conforming to IS 287-1993. Timber to be used for the work shall be from the heart entirely removed. It shall be uniform in substance, straight in fiber, free from large, loose, dead or cluster knots, flaws, shakes, wasp, cup spring, twist, bends and defects of any kind. It should be free from spongy, brittle, flaky or brushy condition, sapwood and borer holes. All timber shall be seasoned and be free from decay, harmful fungi and insect attacks and from any other damage of harmful nature which will affect the strength, durability, appearance or its usefulness for the purpose for which it is required. The samples of the timber shall be approved by the Engineer before use. As the darkness of colour amongst the colour species of timber being a sign of strength and durability, the colour shall be uniform as far as possible. The moisture content for timber shall not exceed 12 percent of dry weight of timber.

Laying

The surface of the parqueting floor shall be made clean, dust free and smooth before laying parqueting timber. Parqueting pattern shall be designed as per contract or drawing or the instruction of the engineer. Required thickness of gluing material such as fevicol shall be evenly spread. Parqueting timber pieces shall be laid in approved pattern over the glue (fevicol). The parqueting floor thus prepared shall be kept safe for drying for two days. The parqueted floor shall be then scraped or planned to an even surface using sanding machine and the whole parqueted floor area shall then be sandpapered. The process of sanding shall be continued till the attainment of desired smooth surface. The floor is polished at the end with the use of approved polish (wax or chapra or French polish). The floor shall not be used till it is not completely dry.

(9) Granite Flooring

Granites should be free from all imperfections and injurious minerals that may interfere with the appearance, strength, structural integrity and its amenability to take good polish. Imperfections are mostly imparted by the textural variations which is a function of degree uniformity and the distribution of the constituent minerals. Hair line cracks/joints, flowers, moles, knots, white and dark lines due to segregation of light-coloured minerals in multi-coloured granites and ferromagnesium minerals in light coloured granites are considered to be the imperfections. Granites should be free from deleterious minerals such as pyrite, marcasite and minerals such as biotite, chlorite, ilmenite, etc, which interfere with the colour and appearance on weathering and also affect polishing characteristics.

The thickness of the granite slab shall be 16 mm and shall be machine cut to required dimensions. The bedding mortar for the granite slab shall be minimum 20 mm thick 1:2 cement: sand mortar. Before laying granite floor it is essential that a level surface is required. The joints shall be as fine as possible. The finished granite flooring shall be cured for a minimum period of seven days. Slight unevenness at the meeting of edges of granite slabs shall be removed by chiselling. The surface shall be ground evenly with machine fitted with finest grade grinding stones. Then oxalic acid shall be dusted over the surface sprinkled with water and rubbed hard with pad and Woolen rags to give smooth and shining finished surface. The floor shall not be used till it is not completely dry.

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(10) Interlocking Concrete block

Interlocking Concrete block units shall be laid in running or stretcher bond as their interlocking design resists the forces that cause creep. Each block is place against the adjacent units without disturbing the other units, developments are taking place at this time relative to mechanized placement of individual units or clusters of blocks that are tied together with break-away webs. The order of laying should be such that it is never necessary to force a block between those already laid.

Where whole units do not fit at the edges of a pavement, cut block are used to fill the spaces. Spaces left around manholes and drainage inlets are treated in the same manner. This is readily accomplished with a small hydraulic block splitter. Spaces less than about 40mm can be filled with cement mortar in 1:2 ratio.

Installation system in brief:

Installation surface shall be clean and free of foreign materials before installing the interlocking blocks. Thickness of interlocking concrete block shall be 50mm or 60mm as specified in the contract or on the drawing. Installation should start from corner or straight edge and proceed forward over the levelled screeding course (Crusher Stone dust 50mm thick). Work shall be plumb, level, and true to line and grade; shall be installed to properly coincide and align with adjacent work and elevations all edges must be retained to secure the perimeter stones and screeding course. Concrete blocks should be installed hand tight and level on the undisturbed screeding bed. The completed paving stone installation should be washed down and cleaned to provide a clean finished workmanlike installation.

(11) Clay tile

The flooring tiles shall be made from good soils of even texture and shall be uniformly well burnt. They shall be uniform in size and shape and shall be free from irregularities, such as twists, bends, cracks, flaws, laminations and imperfections which affect appearance or serviceability. The faces of tiles shall be plain, grooved, fluted or figured as specified and the edges shall be square. The backs of the tile may have some type of either plain or engraved or embossed design.

The dimensions of the square, rectangular and triangular tiles shall range from 150mm to 250mm and thickness from 15mm to 30mm. Dimension of tile shall not vary more than ± 5 mm from the nominal dimension and thickness shall not vary more than ± 2mm. The warpage shall not exceed 2 percent along the edges and 1.5 percent along the diagonals. The tiles shall be laid over cement sand mortar usually in the ratio of 1:2 cement sand of thickness not less than 12mm.

(12) Anti-Slip Cement Tile

Anti-slip cement tiles are designed to provide traction and reduce the risk of slipping or falling, especially in areas prone to moisture or wet conditions. Anti-slip cement tiles often feature a rough or textured surface. This texture can vary depending on the specific tile design, but it is typically created by incorporating raised patterns, grooves, or a roughened finish. The texture helps to enhance grip and prevent slipping, even when the surface is wet or contaminated.

Anti-slip tile of required size and thickness as specified in contract or on the drawing shall be laid in cement sand mortar over a clean, dry, dust free and smooth surface. Sample of workmanship shall be approved prior to execution of work.

(13) Glazed/Non Glazed Tile

Glazed/Non Glazed ceramic tiles shall be of approved colour and make. These shall be of specified size approved by the Engineer.

General

Prior to installing any tile, the Contractor shall inspect surfaces and conditions in areas to receive tile work and shall notify the Engineer of any serious defects or conditions that will interfere with or prevent a satisfactory tile installation and shall co-ordinate with other trades of work.

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Installing the Tile

The surface shall be brushed, cleaned and wetted. Glazed/Non Glazed tile shall be soaked completely by immersing in clean water at least 30 minutes and drained. No free moisture shall be allowed to remain on the backs of the tiles at the time of setting. Tiles shall be installed by applying a skim coat of mix of 1 : 4 (1 cement : 4 sand) cement sand mortar not less than 12 mm thick on wall by firmly pressing tile into the cement mortar applied on the wall so that the back of the tile is completely in touch with the mortar. Joints in the tile work shall be accurately aligned with horizontal joints level and vertical joints in plumb. Joints shall be maintained uniformly 1.5 mm wide or as directed by the Engineer by aligning spacer lugs on tile edges if tiles are so manufactured or by use of wetted strings. Tiles shall be laid out in such a way that no tile is less than half size course. Where tile must be cut at edges or penetrated the cut edges shall be carefully filed and neatly ground. Chipped, cracked or broken tiles shall not be used and all defective work shall be replaced and repaired to the satisfaction of the Engineer at the Contractor's expense. After tiles have been set firm and strings from set tiles removed, tiles shall be dampened and joints grouted full with a plastic mix of white cement by trowel, brush or finger application. During grouting all excess grout shall be cleaned off the tile surface with damp cloth or sponge. All tile work finishing shall be adequately protected from damage during the progress of construction till completion and any damage shall be repaired to the satisfaction of the Engineer at the Contractor's expense. Upon completion prior to final inspection and acceptance, the Contractor shall clean all tile work. Acids or other agents liable to damage the work shall be avoided. If tile surface shows mass scratches, cracks or other imperfections, which cannot be removed by cleaning; the contractor shall remove the defective material and replace with new material at no additional expense. Sample of workmanship shall be approved prior to execution of work.

(14) Vitrified Tile

General

Mat/glazed finish vitrified tiles shall be of homogeneous natural finish of approved colour, model and make. These shall be of specified size approved by the Engineer.

Prior to installing any tile, the Contractor shall inspect surfaces and conditions in areas to receive tile work and shall notify the Engineer of any serious defects or conditions that will interfere with or prevent a satisfactory tile installation and shall co-ordinate with other trades of work.

Installing the Tile

The surface shall be brushed, cleaned and wetted. Tile shall be soaked completely by immersing in clean water at least 30 minutes and drained. No free moisture shall be allowed to remain on the backs of the tiles at the time of setting. Tiles shall be installed by applying a skim coat of plastic mix of 1:6 (1 cement: 6 sand), cement mortar at least 12 mm thick on wall/floor by firmly pressing tile into the cement mortar applied on the wall so that the back of the tile is completely in touch with the mortar. Joints in the tile work shall be accurately aligned with horizontal joints level and vertical joints in plumb. Joints shall be maintained uniformly 1.5 mm wide or as directed by the Engineer by aligning spacer lugs on tile edges if tiles are so manufactured or by use of wetted strings. Tiles shall be laid out in such a way that no tile is less than half size course. Where tile must be cut at edges or penetrated the cut edges shall be carefully filed and neatly ground. Chipped, cracked or broken tiles shall not be used and all defective work shall be replaced and repaired to the satisfaction of the Engineer at the Contractor's expense. After tiles have been set firm and strings from set tiles removed, tiles shall be dampened and joints grouted full with a plastic mix of white cement by trowel, brush or finger application. During grouting all excess grout shall be cleaned off the tile surface with damp cloth or sponge. All tile work finishing shall be adequately protected from damage during the progress of construction till completion and any damage shall be repaired to the satisfaction of the Engineer at the Contractor's expense. Upon completion prior to final inspection and acceptance, the Contractor shall clean all tile work. Acids or other agents liable to damage the work shall be avoided. If tile surface shows mass scratches, cracks or other imperfections, which cannot be removed by cleaning; the contractor shall remove the defective material and replace with new material at no additional expense. Sample of workmanship shall be approved prior to execution of work.

(15) Anti-Acid/Alkali Tile

The tiles shall be of vitreous ware and shall be free from deleterious substances. The finished tile, when fractured, shall appear tine grained in texture, dense and homogeneous. The tiles shall be sound, true to shape, flat, free from flaws and other manufacturing defects affecting their utility. The water absorption shall be less than 0.5% and breaking strength of minimum 1300N. The Tiles shall be resistance to abrasion and resistance to the low or high concentrations of acid and alkali and other household chemicals and salts.

The tiles shall be of required thickness as specified in contract or on the drawing. The tiles shall be laid over 1:4 cement sand mortar whose thickness shall not be less than 12mm. The finished work shall be kept wet for 7 days.

(16) PVC Tile

The PVC flooring provides a clean, dust free, and resilient flooring. The flooring may be easily cleaned with a wet cloth, as dirt and grime do not penetrate the surface. The PVC tile shall be laid in rubber-based adhesives approved by the engineer.

(17) Others

The material used for other works like Dry brick, stone laying, Sand and brick bat filling, Cement punning works, Skirting works, etc shall be as per this specification and other relevant specification under this specification.

1204 MEASUREMENT

Unless stated otherwise, the Cement Concrete, Cement Plaster, Mosaic (Marble Chips and White Cement), Terrazzo Tiles, Marble, Porcelain Glazed Tile, Flagstone, Flat stone, Dense (Teliya) Brick, Brick, Parquet, Stone, Timber, Granite, Interlocking Concrete Block, Clay Tile, Anti slip Cement Tile, Glazed Ceramics Tile, Glazed and Non-Glazed Tile, Vitrified Tile, Anti Acid/Alkali Tile and PVC Tile shall be measured in Sqm as specified in the contract.

1205 PAYMENT

The flooring works as specified shall be paid as per the contract unit rate. The Contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

SECTION 1300: PLASTERING AND POINTING WORKS

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1301 SCOPE

This Section covers the furnishing of materials and plastering and pointing works for Brick and Stone Masonry structures as the case maybe in accordance with the detail shown on the Drawing and these Specifications or as directed by the Engineer.

1302 MATERIALS

Cement Sand mortar shall be mixed in proportion of materials as indicated in the contract. The ingredients shall be accurately measured by volume and shall be well and evenly mixed together before adding required amount of water to make homogeneous paste of workable consistency. If hand mixing is allowed, it shall be done in clean and smooth hard platform. The gauged materials shall be put in the platform and mixed dry thoroughly. Water in required quantity will then be added and the whole mix will be mixed again until it is homogeneous and of uniform colour.

(1) Sand

Sand shall comply with the requirements in accordance with Clause 602 (2) (i) (a).

(2) Cement

Cement shall comply with the requirements in accordance with Clause 602 (2) (i) (b).

(3) Water

Water shall comply with the requirements in accordance with Clause 602 (2) (iii) (b).

1303 FINISHING OF SURFACES

(1) General

The surfaces can be finished by 'jointing', 'pointing' or 'plastering', as specified. For a surface which is to be subsequently plastered or pointed, the joints shall be squarely raked out to a depth, of 15 mm while the mortar is still green. The raked joints shall be well brushed to remove dust and loose particles and the surface shall be thoroughly washed with water, cleaned and wetted.

The mortar for finishing shall be prepared as per Clause 602.

(2) Jointing

In jointing, the face joints of the mortar shall be worked out while still green to give a finished surface flush with the face of the brickwork. The faces of brickwork shall be cleaned to remove any splashes of mortar during the course of raising the brickwork.

(3) Brick Masonry Pointing

For pointing, the mortar shall be filled and pressed into the raked-out joints, before giving the required finish. The pointing shall then be finished to the proper type given on the Drawing. If the type of pointing is not mentioned on the Drawing the same shall be ruled pointing. For ruled pointing after the mortar has been filled and pressed into the joints and finished off level with the edges of the bricks, it shall while still green be ruled along the centre with a half round tool of such width as work shall may be specified by the Engineer. The superfluous mortar shall then be cut off from the edges of the lines and the surface of the masonry shall also be cleaned of all mortar.

(4) Stone Masonry Pointing

Where external faces of the mortared Stone masonry work will be backfilled or otherwise permanently covered up, the mortared joint shall be finished flush to the faces of the adjacent stonework. Where mortared masonry faces will remain exposed, the mortar joints shall be pointed to a consistent style as shown on the Drawing. Pointing shall be carried out using specified mortar of cement and sand as shown on the Drawing. The mortar shall be filled and pressed into the raked-out joints before giving the required finish. The pointing, if not otherwise mentioned, shall be ruled type for which it shall, while masonry work is still green, be ruled along the centre with half round tools of such width as may be specified by the engineer. The excess mortar shall then be taken off from the edges of the lines and shall not be

unnecessarily plastered over the exposed stone works. The thickness of the joints shall not be less than 3mm for Ashlar masonry.

However, the maximum thickness of joints in different works shall be as follows:

Random Rubble: 20 mm

Coursed Rubble: 15 mm

Ashlar masonry: 5 mm

(5) Plastering

Plastering shall be started from top and worked down. All putlog holes shall be properly filled in advance of the plastering as the scaffolding is being taken down. Wooden screeds 75 mm wide and of the thickness of the plaster shall be fixed vertically 2.5 to 4 metres apart to act as gauges and guides in applying the plaster. The mortar shall be laid on the wall between the screeds using the plaster's float and pressing the mortar so that the raked joints are properly filled. The plaster shall then be finished off with a wooden straight edge reaching across the screeds. The straight edge shall be worked on the screeds with a small upward and sideways motion 50 mm or 75 mm at a time. Finally, the surface shall be finished off with a plaster's wooden float. Metal floats shall not be used.

When recommencing the plastering beyond the work suspended earlier, the edges of the old plaster shall be scraped, cleaned and wetted before plaster is applied to the adjacent areas.

No portion of the surface shall be left out in a condition to be patched up later on.

The plaster shall be finished to a true and plumb surface and to the proper degree of smoothness as required by the Engineer.

The average thickness of plaster shall not be less than the specified thickness. The minimum thickness over any portion of the surface shall not be less than the specified thickness minus 3 mm.

Any cracks which appear in the surface and all portions, which sound hollow when tapped, or are found to be soft or otherwise defective, shall be cut out in rectangular shape and re- plastered as directed by the Engineer.

(6) Curing of Finishes

Curing shall be started as soon as the mortar used for finishing has hardened sufficiently not to be damaged when watered. It shall be kept wet for a period of at least 7 days. During this period, it shall be suitably protected from all damages.

1304 TEST AND STANDARD OF ACCEPTANCE

Before laying any cement sand mortar, the Contractor shall make three sets of mortar test cubes from each source of sand to demonstrate the compliance of the mortar to the specified strength. Each set shall comprise two cubes, one to be tested at 7 days and the other to be tested at 28 days. Testing shall be in accordance with IS 2250. During construction the Contractor shall make and test mortar cubes at the rate of three for every 25m^2 or part of it of plastering/pointing work to assess the strength of the mortar subject to a minimum of 3 sample cubes for a day’s work.

1305 MEASUREMENT

All plastering and pointing works shall be measured in square metres separately.

1306 PAYMENT

The plastering and pointing works shall be paid at their respective contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115 to complete the work as per these Specifications.

SECTION 1400: PAINTING WORK

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1401 SCOPE OF WORK

This Section covers different types of painting works and other works related to painting.

1402 GENERAL

The Contractor shall be responsible for painting works as specified in the contract or on the Drawing in accordance with this Section and other relevant Section of these Specification. Before painting begins, the Contractor shall submit to the Engineer drawings showing details of the proposed painting work and other related works, as applicable. The contractor shall submit samples of workmanship of painting works to the Engineer for approval prior to execution of work.

1403 MATERIALS AND PAINTING WORKS

(1) Whitewashing (Lime Painting)

Materials:

Lime - Lime used for whitewashing shall be freshly burnt class 'C' lime (Fat lime) and white in colour conforming to **IS : 712-1984.**

Water - Water to be used for this purpose shall be clear, potable, free from all organic and suspended impurities.

Gum or Glue – Gum or Glue Should be of good quality approved by the Engineer.

Pigments – Pigments if required to be used in painting shall be blue vitriol. Blue vitriol shall be fresh crystals of hydrous copper sulphate (blue vitriol) conforming to **IS: 261-2023** and shall be grounded to fine powder during use.

Preparation of surface:

a) **New Surface** - The surface shall be thoroughly cleaned of all dirt, dust, mortar drops and other foreign matters before whitewash is to be applied.

b) Old Surface

Surfaces, where the same colour-wash is to be repeated - Old surfaces already whitewashed or colour-washed shall be broomed to remove all dust and dirt. All loose scales of lime wash and other foreign matter shall also be removed. Where heavy scaling has taken place the entire surface shall be scraped clean. This will also apply, where a colour wash has to be given on an already whitewashed surface.

Surfaces, where different colour- wash is to be applied - Old colour-wash on surfaces shall be entirely removed before whitewash or different colour-wash is applied. The surface shall be prepared by brushing or by scraping or by other suitable means to produce clean surface and shall be broomed to remove dust, dirt, etc.

Old surfaces spoiled by smoke soot - The surface shall be scraped with steel wire-brushes or steel scrapers. The surface shall then be broomed to remove all dust and dirt and shall be washed with clean water.

Oil and grease spots - Oil and grease spots shall be removed by a suitable chemical and smooth surfaces shall be rubbed with wire-brushes.

Preparation of Whitewash:

Whitewash shall be prepared from fat lime. The lime shall be slaked at site and shall be mixed and stirred with about five liters of water for 1 kg of unslaked lime to make a thin cream. This shall be allowed to be stand- for a period of 24 hours and this shall be screened through a clean coarse cloth. Add 1 kg of gum dissolved in hot water to each m^3 of lime cream. Reasonable quantity of pigment (blue vitriol) if required shall be added to whitewash solution and the whole solution shall be stirred thoroughly before use.

Application of whitewash:

Whitewash shall be applied with suitable brush to the number of coats specified in the contract or on the drawing. The operation for each coat shall consist of a stroke of the brush given from the top downwards, another from the bottom upwards over the first stroke, and similarly one stroke horizontally from the right and another from the left before it dries. Each coat shall be allowed to dry before the next coat is applied. No portion of the surface shall be left out initially to be patched up later on. The brush shall be dipped in whitewash pressed lightly against the wall of the container, and then applied by lightly pressing against the surface with full swing of hand. The whitewashing on ceiling should be done prior to that on walls.

For new surface, generally minimum two coats shall be applied so that the surface presents a smooth and uniform finish through which the plaster does not show. However, it can be one coat or three coats either depending upon the condition of the surfaces to be whitewashed. The finished dry surface shall not show any signs of cracking and peeling and the whitewash shall not come off readily on the hand, when rubbed.

For old surface, after the surface has been prepared, a coat of whitewash shall be applied over the patches and repairs first. After that one coat of whitewash shall be applied thoroughly. If required and mentioned in contract or on the drawing, two or more coats of whitewash may be applied over the entire surface. The whitewashed surface shall present a uniform finish through which the plaster patches do not show.

(2) Distemper

Material

The material shall be in the form of a fine dry, homogeneous powder free from odour of putrefaction as such and when mixed with water. The material shall consist of suitable pigments, extenders lime-proof tinters, water-soluble binders and preservatives mixed in suitable proportions to comply with the requirements of IS427:2013. The material, when mixed with an adequate quantity of water, shall comply with requirements as given in IS 427:2013.

Preparation of surface:

(a) New Surface Preparation:

If the surface is newly plastered surface, it shall be allowed to cure completely. And then allowed to dry such that entire moisture get dried completely. The loose particles, dust, dirt, grease, wax, mortar dropping, etc. shall be removed using wire brush or putty knife. After that, the whole surface shall be wiped off using a dry cloth.

(b) Old Surface Preparation:

If the distemper is to be applied on the existing painted surface, the loose particles, dust, dirt, grease, wax, mortar droppings, growth of fungus, algae, dampness, etc. shall be removed first with the help of a putty knife or wire brush. The surface shall be thoroughly rubbed with sandpaper. After that, the entire surface shall be washed and allowed to dry fully. The holes and cracks (upto 3 mm) shall be filled with the putty and allowed for hardening. The wall shall be made smooth with the use of sandpaper. Finally, the dust shall be wiped off with dry cloth.

Application of distemper:

Distemper can be applied as Base / Lining (Astar) Coat or Single coat or two coat or more than two coat depending upon the nature of the surface, finished surface desired as specified in the contract or on the drawing. Wall putty may be applied if required, before the application of base coat / primer coat. The primer coat/base coat is applied to ensure a good bond between distemper paint and the surface and create a better finish. Primer coat provides the foundation for the paint job and increases the coverage of the paint.

The material (paint) shall be diluted as per the dilution ratio recommended by the manufacturer. The material after thinning shall be suitable for application by brush or a roller. After the application of base

coat/primer coat, the first coat of distemper paint as specified shall be applied with the help of a brush or a roller. The painted surface shall be left to dry. After the drying of the first coat of distemper paint, the second coat as specified shall be applied and surface allowed to dry overnight. After finishing the application of distemper paint, the surface shall be prevented from any dirty materials. The resulting painted surface shall be smooth and uniform and give a fresh new look.

(3) Water Proof Cement Paint

Materials:

Water proofing cement shall be of Nerolac, Burger, Asian Paints or any other equivalent brand as specified in the contract or on the drawing and approved by the Engineer. The materials shall be sealed in tins.

Application:

Water proof cement paint shall be applied in single (one) coat or double (two) coats as mentioned in the contract or on the drawing. Before painting is commenced on surface, all dirt and foreign matters shall be completely removed. The surface shall be wetted by sprinkling water with a fine spray. The surface shall be sprayed several times with a few minutes intervals between each spraying to allow the moisture to soak into the surface. Paint shall be applied on the cleaned surface with a hair brush or a roller. Sample of workmanship shall be approved by the Engineer prior to commencement of work.

A vertical stroke with another horizontal stroke of painting shall be termed as one coat. Paint shall be applied to the surface with hair brushes in a number of coats as specified to get uniform finish. After the first coat of the paint has hardened, it shall be cured with water at least for 24 hours before the second coat is applied. Second coat shall be applied over the first coat and finished smooth and uniform surface shall be kept damp at least for seven days.

(4) Readymade Enamel Paint

Materials

The Enamel paints shall be of Nerolac, Burger, Asian Paints or any other equivalent brand as specified in the contract or on the drawing and approved by the Engineer. The materials shall be sealed in tins.

Preparation of surface

All surfaces shall be thoroughly planed and sand papered. The loose particles, dust, dirt, grease, wax, mortar dropping, etc. shall be removed using wire brush or putty knife.

Application

Enamel paint shall be applied as Base / Lining (Astar) Coat, single coat (first coat only) or two coats (first and second coat) as mentioned in the contract or on the drawing. After preparing the surface and after the priming coat has been applied a top coat (single coat) as specified shall be applied. Another coat (Second coat) as specified shall be applied after the previous coat (first coat) is dry. Care should be taken that dust or other foreign materials do not settle as they will disfigure the painted surface.

The same brand of materials will be used for various coats. The paints shall be used and applied as per manufacturer's printed instruction and direction of the Engineer. The paint shall be applied with bristle brushes and not horse hair ones. The paints shall be applied in the thinnest possible layers with parallel drawings. No flowing down shall be allowed. Painting to false ceiling and acoustic tile, soft board etc. shall be done by spray painting only. Sample of workmanship shall be approved by the Engineer prior to commencement of work.

(5) Plastic Emulsion Paint

Materials

Acrylic coat plastic emulsion shall be of Nerolac, Burger, Asian Paints or any other equivalent brand as specified in the contract or on the drawing and approved by the Engineer. The materials shall be sealed in

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tins.

The material shall consists of pigments and if required suitable extenders in appropriate proportion in a medium consisting of any stable synthetic polymer emulsion in water with other suitable ingredients as may be necessary to produce a material so as to satisfy the requirements of the code IS15489:2024.

The material shall be free from odour of putrefaction. It shall be free from lumps, skins and the conditions of the material shall be such that settling, if any, maybe easily incorporated on stirring.

When suitably thinned with water, the material shall mix readily with minimum amount of foaming to a smooth and homogeneous state. The foaming, if any, shall dissipate rapidly. The material after recommended thinning shall be suitable for application by brush, spray or roller. The resulting film shall not show pigment flocculation, coarseness or other undesirable characteristics.

Application

Plastic Emulsion paint shall be applied as Base / Lining (Astar) Coat, single coat (first coat only) or two coats (first and second coat) as mentioned in the contract or on the drawing. Before application of plastic emulsion paint, all surfaces shall be thoroughly planed and sand papered. Knotting and stopping as required shall be attended. The loose particles, dust, dirt, grease, wax, mortar dropping, etc. shall be removed using wire brush or putty knife.

After preparing the surface and after the priming coat has been applied a top coat (single coat) as specified shall be applied. Another coat (Second coat) as specified shall be applied after the previous coat (first coat) is dry. Care should be taken that dust or other foreign materials do not settle as they will disfigure the painted surface.

The same brand of materials will be used for various coats. The paints shall be used and applied as per manufacturer's printed instruction and direction of the Engineer. The paint shall be applied with brush, spray or roller. The paints shall be applied in the thinnest possible layers with parallel drawings. No flowing down shall be allowed. Sample of workmanship shall be approved by the Engineer prior to commencement of work.

(6) Aluminum Paint

Materials

Aluminum Paint shall be of Nerolac, Burger, Asian Paints or any other equivalent brand as specified in the contract or on the drawing and approved by the Engineer.

The materials shall be sealed in tins.

Application

Aluminum paint shall be applied as Base / Lining (Astar) Coat, single coat excluding astar, two coats excluding astar or two coats including astar as mentioned in the contract or on the drawing. Before application of aluminum paint, all surfaces shall be thoroughly planed and sand papered. The loose particles, dust, dirt, grease, wax, mortar dropping, etc. shall be removed using wire brush or putty knife.

After preparing the surface, the base/astar primer coat shall be applied as specified in the contract. After the priming coat has been applied a top coat (single coat) as specified shall be applied. Another coat (Second coat) as specified shall be applied after the previous coat (first coat) is dry. Care should be taken that dust or other foreign materials do not settle as they will disfigure the painted surface.

The same brand of materials will be used throughout the painting process. The paints shall be used and applied as per manufacturer's printed instruction and direction of the Engineer. The paint shall be applied with brush, roller or spray as the case may be applicable. The paints shall be applied in the thinnest possible layers with parallel drawings. No flowing down shall be allowed. Sample of workmanship shall be approved by the Engineer prior to commencement of work.

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(7) Double boiled linseed oil

Materials:

Double boiled linseed oil shall be of Pure Tung Oil (manufactured in China), Watco Danish Oil, Behlen's Boiled Linseed Oil (both manufactured in USA) or any other equivalent brand as specified in the contract or on the drawing and approved by the Engineer. The materials shall be sealed in tins. It shall be clear and free from sediment and other insoluble matters.

Application:

Double boiled linseed oil can be used on wood surfaces, or metal for rust prevention, water repellence, as a lubricant or a sealer. Double boiled linseed oil shall be applied as single coat or Second coat or additional coats as mentioned in the contract or on the drawing. Before application of double boiled linseed oil, all surfaces shall be thoroughly planed and sand papered. The loose particles, dust, dirt, grease, wax, mortar dropping, etc. shall be removed using appropriate brush or wire brush.

The oil shall be applied in layers (one layer or two layers or more than two layers) as required by the contract using cloth or brush. The previous layer shall be allowed to dry for at least 6 hours before placing another layer. The surface shall be made smooth by using sandpaper between layers. . The resulting oiled surface shall be smooth and uniform and give a fresh new look. Sample of workmanship shall be approved by the Engineer prior to commencement of work.

(8) Varnish

Materials:

Varnish shall be of Berger, Asian paints, Nippon, Shalimar or any other equivalent brand as specified in the contract or on the drawing and approved by the Engineer. The materials shall be sealed in tins. The material shall be clear, transparent and free from foreign matter, sediment and undissolved water. It shall have required resistance to water when tasted as per IS: 101.

Application:

Varnish can be used on wood surfaces as water repellence, a lubricant or a sealer. Varnish shall be applied as single coat or Second coat or additional coats as mentioned in the contract or on the drawing. Before application of Varnish, all surfaces shall be thoroughly planed and sand papered. The loose particles, dust, dirt, grease, wax, mortar dropping, etc. shall be removed using appropriate brush or sandpaper.

The varnish shall be thoroughly stirred using a stir stick or a wooden dowel. Due care shall be taken to avoid shaking the container vigorously as it can introduce air bubbles which are not desireable. The varnish shall be applied in layers (one layer or two layers or more than two layers) as required by the contract using high-quality brush specifically designed for varnish application. The previous layer shall be allowed to dry sufficiently before placing another layer. The surface shall be made smooth by using sandpaper and soft cloth between layers. The resulting finished surface shall be smooth and uniform and give a pleasant look. Sample of workmanship shall be approved by the Engineer prior to commencement of work.

(9) Bitumen paint

Materials:

Bitumen paint shall be of Asian paints or any other equivalent brand as specified in the contract or on the drawing and approved by the Engineer. The materials shall be sealed in tins. The material shall be adequately flexible and elastic having water proofing, corrosion protecting and adhesive characteristics.

Application:

Bitumen paint can be used on roof as water proofing material and even on the metal surface to create protective coating. Bitumen paint shall be applied as single coat or Second coat or additional coats as mentioned in the contract or on the drawing. Before application of bituminous paint, all surfaces shall be

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thoroughly cleaned. The loose particles, dust, dirt, grease, wax, mortar dropping, etc. shall be removed using appropriate brush or sandpaper.

The bituminous paint shall be thoroughly stirred using a stir stick or a paint mixer to ensure a consistent mixture and proper application. The bituminous paint shall be applied in layers (one layer or two layers or more than two layers) as required by the contract using brush, roller, or spray gun.

The previous layer shall be allowed to dry sufficiently before placing another layer. The surface shall be made smooth by using sandpaper and soft cloth between layers. The resulting finished surface shall be smooth and uniform and give a pleasant look. Sample of workmanship shall be approved by the Engineer prior to commencement of work.

(10) Chapra (Resin) Polish

Materials

The material required for Chapra polish shall be Chapra, Ramtilak, Sprit, Geru, sand paper, color, shining polish, etc. as specified in contract or on the drawing.

Preparation of surface

Chapra polish is generally applied on wood works such as wooden parqueting, wooden railings, wooden furniture, wooden cupboards, wooden doors and windows, frames and shutters, etc. All surfaces, where polish is to be applied shall be thoroughly planed and sand papered. Knotting and stopping as required shall be attended. The loose particles, dust, dirt, grease, wax, mortar dropping, etc. shall be removed using appropriate brush or sandpaper.

Application

After applying the priming coat on the prepared surface, a topcoat shall be applied. It shall be allowed sufficiently to get dry. Following coats as required and specified in contract shall be applied when the previous coat is completely dry. Due care should be taken that dust or other foreign materials do not settle on the painted surface as they will disfigure the painting. The finished surface shall be smooth, pleasant and glowing/shining to the satisfaction of the Engineer. Sample of workmanship shall be approved by the Engineer prior to commencement of work.

(11) Red oxide paint

Materials

Red oxide paint shall be of Berger, Asian paints, Shalimar or any other equivalent brand as specified in the contract or on the drawing and approved by the Engineer. The materials shall be sealed in tins.

Preparation of surface

Red oxide paint is generally applied on metals to protect them from rusting. The surface to be painted shall be clean, dry, and free from dust, grease, rust, and other contaminants. Any loose paint or rust shall be removed using wire brushing or sanding.

Application

Red oxide paint shall be applied as single coat or double coat as mentioned in the contract or on the drawing. The red oxide paint shall be thoroughly stirred to ensure uniform consistency. If the paint has separated or settled, it shall be mixed

well using a stir stick or a paint mixer. After applying the priming coat, if required and specified in the contract, on the prepared surface, a topcoat shall be applied using high-quality brush, roller, or spray equipment. It shall be allowed sufficiently to get dry. Following coats as required and specified in contract shall be applied when the previous coat is completely dry. Due care should be taken that dust or other foreign materials do not settle on the painted surface as they will disfigure the painting. The finished surface shall be smooth, protective and agreeable to the satisfaction of the Engineer. Sample of workmanship shall

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be approved by the Engineer prior to commencement of work.

(12) Cement paint

Materials:

Cement paint shall be of different brands or any other equivalent brand as specified in the contract or on the drawing and approved by the Engineer. The materials are found sealed in sacks.

Application:

Cement paint shall be applied in single (one) coat or double (two) coats as mentioned in the contract or on the drawing. Before painting is commenced on surface, all dirt and foreign matters shall be completely removed. The surface shall be wetted by sprinkling water with a fine spray. The surface shall be sprayed several times with a few minutes intervals between each spraying to allow the moisture to soak into the surface. Paint shall be applied on the cleaned surface with an appropriate brush or a roller. Sample of workmanship shall be approved by the Engineer prior to commencement of work.

A vertical stroke with another horizontal stroke of painting shall be termed as one coat. Paint shall be applied to the surface with hair brushes in a number of coats as specified to get uniform finish. After the first coat of the paint has hardened, it shall be cured with water at least for 24 hours before the second coat is applied. Second coat shall be applied over the first coat and finished smooth and uniform surface shall be kept damp at least for seven days.

(13) Plastic Felt

General:

Plastic felt, also known as synthetic roofing underlayment or synthetic roofing felt, is a synthetic material used as an alternative to traditional roofing felt. It provides waterproofing and protection for roofs during construction or as an additional layer under roofing materials.

Materials:

Plastic Felt shall be of different brands or any other equivalent brand as specified in the contract or on the drawing and approved by the Engineer. The materials are found in rolls.

Application:

Plastic felt shall be applied in single (one) layer or double (two) layers as mentioned in the contract or on the drawing. Before laying plastic felt on surface, all dirt and foreign matters shall be completely removed. The surface shall be cleaned with brush and by sprinkling water with a fine spray. Plastic felt shall be spread over the cleaned surface with due over lapping. The plastic felt shall be secured to the roof surface using appropriate fasteners such as nails, staples, or plastic cap nails, following the manufacturer's recommendations for the spacing and type of fasteners to ensure proper attachment. Subsequent rows of plastic felt shall be installed with overlapping each sheet by a specified distance (typically around 6 inches or as recommended by the manufacturer) to help create a continuous waterproof barrier. Finished surface shall be smooth and well stretched with due gradient for drainage. Sample of workmanship shall be approved by the Engineer prior to commencement of work.

(14) Primer

Materials:

The primers shall be of Nerolac, Burger, Asian Paints (tractor) or equivalent brand as specified in the contract or on the drawing and approved by the Engineer. The primers shall be in sealed tins.

Preparation

All surfaces shall be papered by sandpaper rubbing and cleaned properly. The surface to be treated shall be clean, dry, and free from dust, grease, rust, and other contaminants. Any loose matter or rust shall be removed using wire brushing or sanding. In case of metal, derusting shall be done and properly cleaned

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after sand papering.

Application

Primer shall be applied in single (one) coat as mentioned in the contract or on the drawing. After preparing the surface, the priming coat shall be smoothly applied with hair brushes or other applicable tool as per manufacturer's printed instructions. The finished surface shall be smooth to receive other coat of paintings.

(15) Anti-Termite Chemical

General:

Termites are basically of two types - Subterranean or ground nesting termites and Non-subterranean or wood nesting termites. Subterranean or ground nesting termites build nests in the soil and live in them, whereas Non-subterranean or wood nesting termites live in wood with no contact with soil.

Anti-Termite chemicals are used for the eradication and control of termites. These chemicals also known as wood preservatives are used as paint or coating to protect

wooden structures from non-subterranean or wood nesting termites. These chemicals, commonly known as termiticides, are designed to either repel termites or kill them upon contact.

Materials and applications:

Anti-termite chemicals such as Chlorpyrifos 20EC, etc. available in packed tins are used after required dilution as barrier between the soil and the foundation of the building for eradication and control of Subterranean or ground nesting termites.

Non-subterranean or wood nesting termites shall be controlled or killed using different chemicals, as specified in the contract and approved by Engineer, such as Borate-based wood preservatives, Copper-based wood preservatives, Synthetic pyrethroid-based wood preservatives, etc. available in packed tins.

Borate-based wood preservatives: Borate compounds, such as disodium octaborate tetrahydrate (DOT), if approved by engineer to use, shall be used as a termite deterrent. Borate compounds shall be dissolved in water and applied as a paint or sprayed onto the wood surface.

Copper-based wood preservatives: Copper compounds, such as copper naphthenate or copper azole, if approved by engineer to use, shall be used in wood preservatives. Copper compounds have insecticidal properties and help protect the wood from termite attacks. These preservatives shall be applied as a coating or pressure-treated into the wood.

Synthetic pyrethroid-based wood preservatives: Some wood preservatives utilize synthetic pyrethroids, such as permethrin or cypermethrin. These chemicals have insecticidal properties and can repel or kill termites. They shall be applied as paint or coating on the wood surface.

(16) Plaster of Paris

General:

The plaster of Paris shall be of semi – hydrate variety calcium sulphate. Its fineness shall be such that when sieved through a sieve of IS sieve designation 3.35mm for 5 minutes, after drying the residue left on it shall be not more than 1% by weight. It shall not be too quick setting. Initial setting time shall not be less than 13 minutes.

Preparation of Surface:

Projecting burrs of mortar formed during existing cement plaster shall be removed. The surface shall be scrubbed clean with wire brushes. In addition, the plastered surface shall be pock marked with pointed tool, at spacing of not more than 4cm centers and depth of pocks to be approx. 3mm deep. This is to ensure a proper key for the plaster. The surface shall be cleaned of oil and grease marks etc.

Application:

The material shall be mixed with water to a workable consistency. Plaster of Paris shall be applied directly on the wall and ceiling plasters as required in suitable size panels and finished to a smooth surface by a steel trowels. The plaster shall be applied in such a manner that it fully fills the gaps the thickness over the plastered surface shall be as specified in the contract or on the drawing and approved by Engineer. The finished surface shall be smooth and true to plane, slopes or curves as required and to the satisfaction of the Engineer.

(17) Rain Seal Paint

Material:

Rain seal paint is a type of paint that provides enhanced water resistance and protection against moisture-related damage. It is commonly used on exterior surfaces exposed to rain, such as wood, concrete, masonry, and stucco. Rain seal paint available in packed tins in different brands such as Behr Premium Plus Ultra Exterior Paint, Sherwin-Williams Duration Exterior Acrylic Coating, Benjamin Moore Aura Exterior Paint, Dulux Weather shield Exterior Paint shall be used as per contract or drawing and the approval of Engineer.

Preparation of Surface:

The surface shall be prepared such that it is clean, dry, and free from dirt, dust, grease, and loose or peeling paint. Any cracks or imperfections on the surface shall be repaired properly. Finally, the surface shall be made smooth using sandpaper if needed.

Application:

After the preparation of surface, Rain seal paint shall be applied. Primer, if required and mentioned in the contract, shall be used before the application of paint. The rain seal paint shall be applied using a brush, roller, or sprayer, following the manufacturer's recommended application techniques and coverage rates. Painting shall be started from the top and worked the way down to ensure even and smooth coverage. The painted surface shall be allowed to dry according to the manufacturer's instructions. The dry surface shall be cured for 1 to 2 hours depending on temperature and humidity conditions of the work area. Additional coats shall be applied depending on the desired level of protection and the specific product as specified in the contract. If additional coats are necessary as per the contract, following coats shall be applied only after drying the previous coat.

1404 MEASUREMENT

Unless stated otherwise, the Whitewashing (Lime Painting), Distemper, Waterproof / Cement Paint, Readymade Enamel Paint / Plastic Emulsion Paint, Aluminum Paint, Double boiled linseed oil, Varnish, Bitumen paint, Chapra (Resin) Polish, Red oxide paint, Cement paint, Plastic Felt, Primer, Anti-Termite Chemical, Plaster of Paris and Rain Seal Paint shall be measured in Sqm.

1405 PAYMENT

The Whitewashing (Lime Painting), Distemper, Waterproof / Cement Paint, Readymade Enamel Paint / Plastic Emulsion Paint, Aluminum Paint, Double boiled linseed oil, Varnish, Bitumen paint, Chapra (Resin) Polish, Red oxide paint, Cement paint, Plastic Felt, Primer, Anti-Termite Chemical, Plaster of Paris and Rain Seal Paint shall be paid as per the contract unit rate. The Contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

SECTION 1500 – RIVER TRAINING AND GABION WORKS

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1501 MANUAL WOVEN GABIONS

(1) Scope

This Clause covers the furnishing of materials and construction of gabion works required for water resources and irrigation-channel protection and river training, including gabion buttresses, retaining walls, spurs, launching aprons, bank and slope protection, check dams, and other associated erosion-control structures. The works shall be provided at locations shown on the Drawings or directed by the Engineer.

(2) Materials

(a) Stone

Stones used for filling the gabion boxes or mattresses shall be clean, hard, sound, unweathered and angular rock fragments or boulders. The specific gravity of the stone shall be not less than 2.50, and the stones shall not absorb water more than 5 percent when tested as per IS: 1124. The length of any stone shall not exceed three times its dimension of the mesh of the crate. However, smaller size of stones as spalls shall be allowed for filling voids and its volume including voids shall not be more than 20 percent of the total volume of the stone. Before filling any gabion boxes and mattresses the Contractor shall submit representative samples of the rock he proposes to use in the gabion for approval by the Engineer. Further representative samples shall be submitted for approval each time when there is a change in the type and strength of the rock.

(b) Gabion

Gabions shall consist of steel wire mesh crates. The steel wire shall be mild steel wire complying with NS 163-2045. Unless specified otherwise in the contract or on the drawing, all wires used in the manufacturing crates and diaphragms, binding and connecting lids and boxes shall be galvanized with a heavy zinc coating by an electrolytic or hit dip galvanizing process. The weight of deposition of zinc shall be in accordance with NS: 163. Zinc coating shall be uniform and be able to withstand minimum number of dips and adhesion test specified as per NS: 163. Tolerance on diameter of wire shall be ± 2.5 percent. The tensile strength shall be between 350 to 550 N/mm^2.

In case of rectangular meshed gabion, the wire shall be woven into a rectangular mesh of specified dimensions with two-way knots. Gabions with rectangular mesh shall not have diaphragms. In case of Hexagonal mesh, the wire shall be woven into a hexagonal mesh with a minimum of 2 twists as shown in fig 15.1. All edges of the crates shall be finished with a selvedge wire at least 2 gauges heavier than the mesh wire. Gabions with hexagonal mesh shall be manufactured in the standard sizes with specified mesh and wire sizes as shown in Table 15.1.

Diaphragms if required, shall be manufactured of the same materials as the parent gabion box and shall have selvedge wire throughout their perimeter. The number and size of diaphragms to be provided with each crate in case of hexagonal meshed gabion, shall be as given in Table 15.1. All crates shall be supplied with binding and connecting wire of the gauges shown in Table 15.1 of sufficient quantity to bind all diaphragms and closing edges.

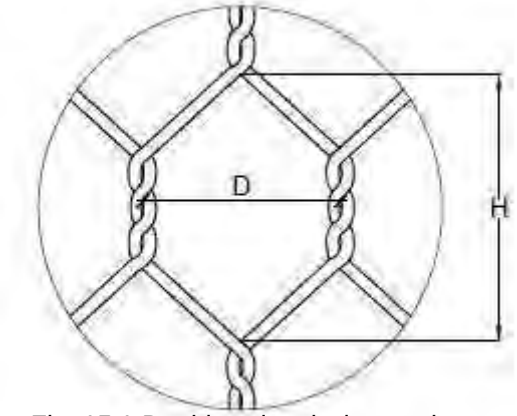

Fig. 15.1 Double twisted wire mesh

Table 15.1: Standard Size of Hexagonal Wire Mesh Gabions

Mesh Type (DXH)	**10 X 12**	**8 X 10**	**6 X 8**
'D', mm	**100**	**80**	**60**
Wire Type	**Heavy Zinc coated or other coating as specified**		
Mesh Wire Dia., mm / SWG	3.25/10	3.25/10	2.64/12
Edge / Selvedge wire Dia., mm/ SWG	4.06/8	4.06/8	3.25/10
Lacing wire dia, mm/ SWG	2.64/12	2.64/12	2.03/14
Typical Sizes Length x Width x Height (m) / Number of diaphragms	Box Gabions: 3 x 1 x 1 / 2 Nos, 2 x 1 x 1 / 1 No, 1.5 x 1 x 1 / 0 No, 3 x 1 x 0.75 / 2 Nos, 2 x 1 x 0.75 / 1 No, 3 x 1 x 0.5 / 2 2 x 1 x 0.5 / 1 No , 1 x 1 x 0.5 / 0 Nos, ,3 x 1 x 0.3 / 2 2 x 1 x 0.3 / 1 No , 1 x 1 x 0.3 / 0 Nos, ,		
Tolerances in Size of Gabion Boxes	Gabion boxes ± 3%, mesh opening +16 % to - 4 %,		

(3) General Requirements

Before filling any gabion boxes and mattresses, the Contractor shall submit samples of gabion boxes and/or gabion mattresses assembled, erected and filled with stones for approval which, when approved, shall be retained for reference and comparison with the gabions built as part of the permanent works. The size, type and location of the samples shall be as directed by the Engineer.

Gabion boxes and gabion mattresses shall be assembled, erected and filled with stones in the dry on prepared surfaces except as may be otherwise approved. Approval for assembling and erecting gabions in water shall be given only, if in the Engineer's opinion such a method will produce work which is otherwise in accordance with the Specification.

(a) Preparation of Foundation and Surface for Bedding

The bed on which the gabion boxes or mattresses are to be laid shall be even and conform to the levels shown on the Drawing. If necessary, cavities between rock protrusions shall be filled with material similar to that specified for gabion filling.

(b) Arrangement of Joints

(i) Walls

In walls gabion boxes shall be placed such that vertical joints are not continuous but staggered. Aprons shall be formed of headers. If more than one unit is required to obtain the necessary width, unit of unequal length shall be used and the joints between should be staggered.

(ii) Channel linings/Slope Protection

In channel linings, gabion box and mattress units shall be laid so that the movement of stone inside the mesh due to gravity or flow of water is avoided. Hence, on side slopes, units shall be placed with their internal diaphragms, if provided, at right angles to the direction of the slope and, on inverts, as far as possible, at right angles to the direction of flow.

(c) Assembly

Gabion boxes and gabion mattresses shall be assembled on a hard flat surface. After fabrication, unpacking or unfolding, they shall be stretched out and any kinks shall be removed. Creases shall be in the correct position for forming the boxes or mattress compartments. The side and end panels shall be folded into an upright position to form rectangular boxes or compartments. The top corners shall be joined together with the thick selvedge wires sticking out of the corners of each panel. The tops of all sides and partitions shall be leveled except as may be appropriate to special units. The sides and end panels shall

be tied together using binding wire of the thickness given in Table 15.1/ 15.4, starting at the top of the panel by looping the wire through the corner and twisting the wire together. Binding shall continue by looping the wire through each mesh and around both selvedges with three rounds which shall be joined tightly together by twisting and the end shall be pocked inside the unit. The diaphragms shall be secured in their correct positions by binding in the same way. The bindings wire shall be fixed using 250 mm long nose fencing pliers or equivalent approved tools.

The gabion boxes and gabion mattresses shall be laid in such a manner that the hinges of the lid will be on the lower side on slopes and on the outer side in walls.

Where mattresses are laid horizontally hinges shall not be placed on the downstream side.

(d) Filling

Except in the case of sack gabions, the crates shall be placed in their final position before filling commences. They shall be stretched to their full dimension and securely pegged to the ground or wired to adjacent gabion before filling. The vertical corners shall be kept square and to full dimension by inserting a steel bay of at least 20 mm diameter at each vertical corner, maintaining it in the correct final position throughout the filling process, and removing it when the crate is full. Before filling commences, the selvedges of the crate shall be bound to the selvedges of adjacent crates with binding wire. Where crates are being assembled in position in a wall the binding of the edges of each crate, the assembly process and the binding together of adjacent crates shall be carried out in the same operation.

Before filling with stone, gabion shall be anchored at one end or side and stretched from the opposite end or side by inserting temporary bars and levering them forward. The top and bottom shall be kept stretched by tensioning with tie wires attached to an anchorage or equivalent approved method until the gabion has been filled. The gabions shall be inspected at this stage but before filling with stone to ensure that the tie/wiring has been properly carried out and the gabion boxes or gabion mattresses are not pulling apart. Gabion boxes or gabion mattresses may be tensioned either singly or in the case of a long straight structure by staining a number of units together using an approved tensioning system.

The filling shall be carried out by placing individual stones into the gabion by hand in courses in such a manner that the stones are bedded on each other and bonded as in dry random rubble masonry as per Clause 708. No loose stones shall be tipped into the crate and the practice of coursing and bonding the outer layer and filling the interior with unlaid stones shall not be permitted.

All the gabions exposed to outer surface shall be provided with bracing. All 1m deep gabions shall be filled in three equal layers and 0.5 m deep gabions in two equal layers. Horizontal bracing wires made with the same bindings wire as used for tying shall be fixed directly above each layer of the stone in the compartments, the wires being looped round two adjoining meshes in each side of the compartment and joined together to form a double tie which shall be tensioned by wind lacing together to keep the face of the gabions even and free from bulges. Bracing wires shall be spaced horizontally along and across the gabions at distances not greater than 0.5 m. Where the upper faces of gabion boxes are not covered with further gabions vertical bracing wires shall be fitted between the top and bottom mesh using two tie wires per square meter of surface.

The ties shall be fixed to the bottom of the units prior to filling and tied down to the lid on completion. Where a double layer of gabion boxes is used to form an apron both upper and lower layers shall have vertical tie wires.

(e) Securing Lids

The gabion boxes and mattress compartment shall be over filled by 50 mm above their tops to allow for subsequent settlement. The lids shall then be tied down with binding wire to the tops of all partition panels. The lids shall be stretched to fit the sides exactly by means of suitable tool but due care shall be taken to ensure that the gabions are not so full that the lids are overstretched. The corners shall be temporarily secured first.

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(4) Test and Standard of Acceptance

(a) The gabion wire shall be tested for mass, uniformity and adhesion of zinc coating and tensile strength of the wire itself. Failure of test results to comply with the specifications shall lead to the rejection of gabion wires. The test on the samples taken as per Table 15.2 from each lot of the G.I. wire received at the side of the work shall be carried out in accordance with NS 163-258.

Table 15.2: Scale of Sampling and Permissible Number of Defective

No. of coils in a lot	No. of coils randomly selected for sampling*	Permissible no. of defective coil
**Upto 25		0
26-50	3	0
51-150	5	0
151-300	8	1
300 and above	13	1

* *One sample per coil shall be tested in all respect*

*** Up to 25 No of coils the contractor shall submit the manufacture's certificate complying the required specification to the Engineer. The manufacturer should have got the NS mark for the production of GI wire from Nepal Bureau of standard and Methodology,*

(b) The stones shall be tested for specific gravity and water absorption. At least 3 set of tests shall be made for every source of material. The test results shall meet the specified criteria.

(5) Measurement

Gabion wire mesh for boxes and mattresses shall be measured in sq. meter. The boxes and mattresses shall be physically measured and verified with their tolerances.

The binding wires, selvedge wire and tension wires shall not be measured separately. They are deemed to be included in the measurement of the gabion boxes and/or mattresses.

Stone filling in gabions including fixing of gabion in position, tying with binding wires and tension wires as specified shall be measured in cu.m.

(6) Payment

Gabion boxes, gabion mattresses, stone filling shall be paid as per respective contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115 to complete the work in accordance with these Specifications.

1502 MECHANICALLY WOVEN CRATES (GABIONS AND MATTRESS)

(1) Scope

This specification covers mechanically woven, mechanically selvedged gabions and Reno mattresses produced from double twist wire mesh used for manufacturing, assembling and installation of the product.

This specification covers gabions and Reno mattresses in which the mesh wire, lacing wire and the selvedge wire are (1) Zn coated (2) Zn + PVC (Poly Vinyl Chloride) coated.

Gabions and mattresses shall be manufactured with all components mechanically connected at the production facility. The front, base, back and lid of the gabions shall be woven into a single unit. The diaphragms shall be factory connected to the base. The lid of the Reno mattresses may be a separate piece made of same type of mesh as the basket.

(2) Terminology

Double twisted wire mesh: a non-raveling mesh made by twisting continuous pairs of wires through three one-half turns (commonly called double-twisted) as shown in fig 15.1, to form hexagonal shaped openings

which are then interconnected to adjacent wires to form hexagonal openings.

Gabion: Gabions (figure 15.2) are boxes made of hexagonal double twisted woven wire mesh, divided into cells by means of diaphragms which help to reinforce and strengthen the structures. They are interconnected with other similar units and filled with stones at the project site to form flexible, permeable and monolithic structures such as gravity retaining walls, channel linings, weirs etc.

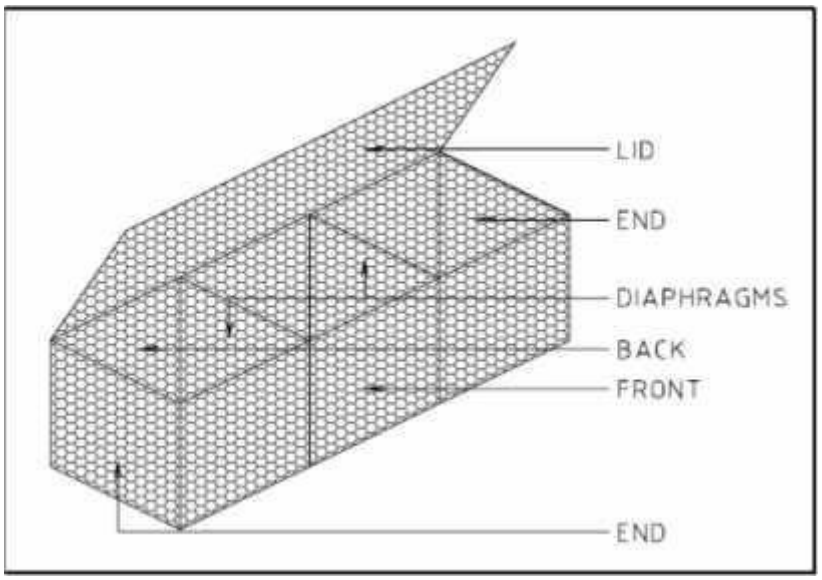

Fig. 15.2 Gabion Box

Jumbo Gabion: Jumbo Gabion, if applicable is a special form of gabion with width 1.5 m or 2 m made of hexagonal double twisted woven wire mesh, divided into cells by means of diaphragms which help to reinforce and strengthen the structures. They are interconnected with other similar units and filled with stones at the project site to form flexible, permeable and monolithic structures such as gravity retaining walls, channel linings, weirs etc.

Reno Mattresses: Reno mattress (figure 15.3) is a special form of gabion with large plan area / thickness ratio, uniformly partitioned into internal cells by means of diaphragms and having smaller mesh openings than the mesh used for gabions. Reno mattresses are generally used in river training works such as riverbank protection, channel lining, launching apron etc.

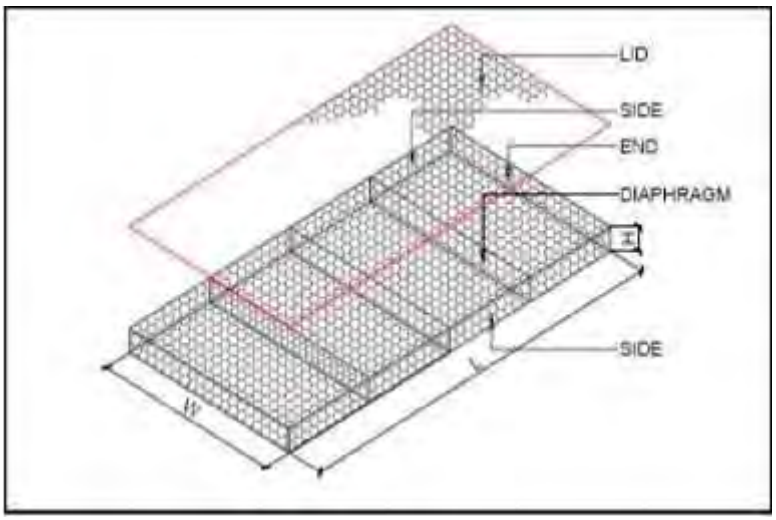

Fig. 15.3 Reno Mattress

Selvedge Wire: a terminal wire used to edge the cut portion of wire mesh panel perpendicular to the double twist by mechanically wrapping the mesh wires around it (Fig 15.4).

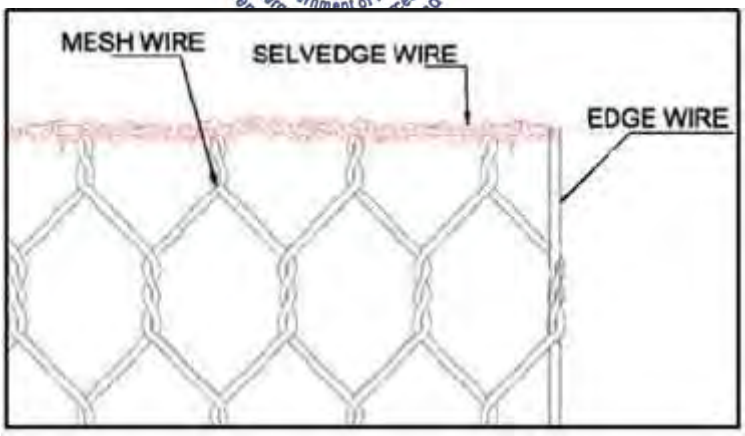

Fig. 15. 4 Mechanically Selvedging and Edge Wire

Main Body: All edges of the standard gabions should be mechanically selvedged (Figure 15.5) in such a way as to prevent unraveling of the mesh and to develop the full strength of the mesh.

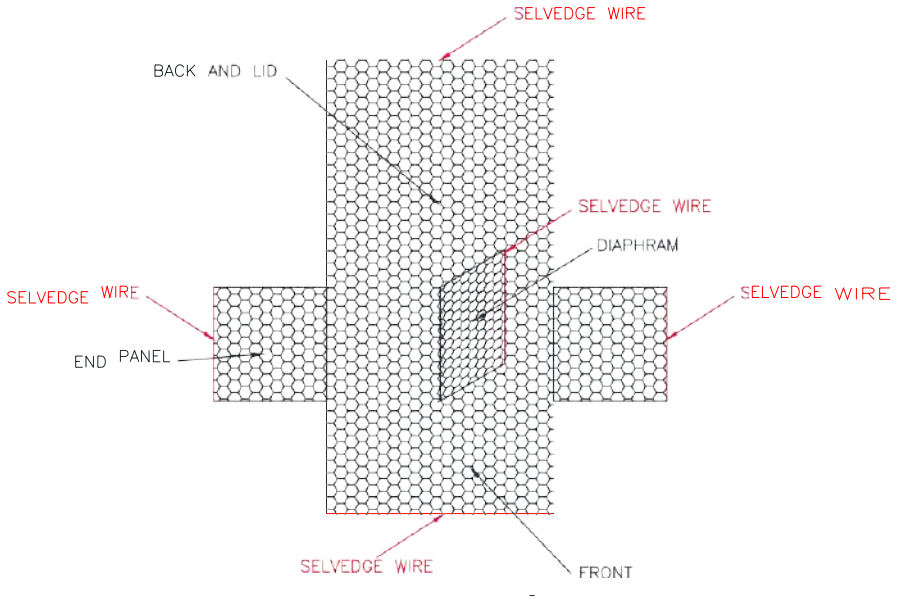

Fig 15.5 Components of Gabions

End panels and internal diaphragms: All sides of end panels and internal diaphragms, except the bottom, should be mechanically selvedged (Figure 15. 4) in such a way as to prevent unraveling of the mesh and to develop the full strength of the mesh.

Edge Wire: a terminal wire of the same diameter as the selvedge wire used to edge the wire mesh parallel to the double twist by continuously weaving it mechanically into the wire mesh (Fig 15.4).

Lacing Wire: a wire with the same coating as per mesh wire used to assemble and interconnect empty units to close and secure stone-filled units and for internal stiffeners.

Diaphragm: an internal partition made of same double twisted wire mesh panel in a gabion / Reno mattress that is attached to the bottom, the sides, and, after the gabion cage is packed with stones, to the lid of the cage (Fig 15.2 and 15. 3).

Connection of end panels to main body: The end panels in Box gabions should be mechanically connected with the main body at the manufacturing site by Selvedging the both to a common selvedge wire in such a way to prevent the separation of the end panel from main body even in extreme conditions (Figure 15.2). In Reno mattresses, the end panels are manufactured together with the main body and are folded at manufacturing site to form the end panels

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(3) Mesh and Box Characteristics

Mesh types and shapes shall be as given in Table 15.3. The mesh and Box characteristics of Gabions and Reno Mattresses are given in Table 15.4 and 15.5.

Table 15.3 Mesh types and size

Mesh type	'D' Nominal Size, mm	Tolerances
10 x 12	100	+ 16% to – 4%
8 x 10	80	
6 x 8	60	

Table 15.4 (A) – Mesh & box characteristics for Gabions					
Mesh Type	10 x 12				
'D', mm	100				
Wire Type	Zn Coated		Zn + PVC Coated (water side one face thicker)	Zn + PVC Coated	Zn +PVC Coated (water side one face) and other faces Zn coated
Mesh Wire Dia., mm	2.70	3.00	Water Side Face – 3.00/4.00 Other Sides- 2.70/3.70*	2.70/3.70*	Water Side Face – 3.00/4.00 Other Sides- 3.00
Edge / Selvedge wire Dia., mm	3.40	3.90	3.40/4.40*	3.40/4.40*	3.90
Lacing wire dia, mm	2.20	2.40	2.20/3.20	2.20/3.20	2.40
PVC coating thickness, mm	N. A		Nominal – 0.50 Minimum – 0.38	Nominal – 0.50 Minimum – 0.38	Nominal – 0.50 Minimum – 0.38
Typical Sizes Length x Width x Height (m) / Number of diaphragms	Box Gabions: 4 x 1 x 1 / 3 Nos, 3 x 1 x 1 / 2 Nos, 2 x 1 x 1 / 1 No, 1.5 x 1 x 1 / 0 No, 1.5 x 1 x 0.5 / 0 No ,2 x 1 x 0.5 / 1 No , 3 x 1 x 0.5 / 2 Nos, 4 x 1 x 0.5 / 3 Nos, Jumbo Gabions: NA				
Tolerances in Size of Gabion Boxes	Length & Width... ± 5%: Height ± 5%				

Table 15.4 (B) – Mesh & box characteristics for Gabions					
Mesh Type	8 x 10				
'D', mm	80				
Wire Type	Zn Coated		Zn – Al alloy Coated	Zn + PVC Coated	Zn – Al alloy + PA6 Coated
Mesh Wire Dia., mm	2.70	3.00	NA	2.20/3.20*	NA
Edge / Selvedge wire Dia., mm	3.40	3.90		2.70/3.70*	
Lacing wire dia, mm	2.20	2.40		2.20/3.20	
PVC coating thickness, mm	N. A		N. A	Nominal – 0.50 Minimum – 0.38	NA

Table 15.4 (B) – Mesh & box characteristics for Gabions				
Mesh Type	8 x 10			
'D', mm	80			
Wire Type	Zn Coated	Zn – Al alloy Coated	Zn + PVC Coated	Zn – Al alloy + PA6 Coated
Typical Sizes Length x Width x Height (m) / Number of diaphragms	Box Gabions: 4 x 1 x 1 / 3 Nos, 3 x 1 x 1 / 2 Nos, 2 x 1 x 1 / 1 No, 1.5 x 1 x 1 / 0 No, 1.5 x 1 x 0.5 / 0 No ,2 x 1 x 0.5 / 1 No , 3 x 1 x 0.5 / 2 Nos, 4 x 1 x 0.5 / 3 Nos,			
Tolerances in Size of Gabion Boxes	Length & Width... ± 5%: Height ± 5%			

Table 15.4 (C) – Mesh & box characteristics for Reno Mattresses					
Mesh Type	6 x 8				
'D', mm	60				
Wire Type	Zn Coated		Zn – Al alloy Coated	Zn + PVC Coated	Zn – Al alloy + PA6 Coated
Mesh Wire Dia., mm	2.70		NA	NA	NA
Edge / Selvedge wire Dia., mm	3.4				
Lacing wire dia, mm	2.20				
PVC coating thickness, mm	N. A		N. A	NA	NA
Typical Sizes Length x Width x Height (m) / Number of diaphragms	6 x 2 x 0.30 / 5 Nos, 5 x 2 x 0.30 / 4 Nos, 4 x 2 x 0.30 / 3 Nos, 3 x 2 x 0.30 / 2 Nos				
Tolerances in Size of Gabion Boxes	Length & Width... ± 5%: Height ± 10%				

- Internal Diameter / External diameter of PVC coated wire
- Only standard sizes of Reno Mattresses are indicated in the table above. Special sizes can also be applied as per instruction of the Engineer.

The Zn coating shall be heavy coating for soft condition conforming to NS 163. For corrosive environment, an additional PVC coating (as per ASTM A 975-2011 of 0.5 mm thick shall be provided over the Zn coating.

(4) Mechanical Properties

Where mesh and connection strength is specified, the minimum strength requirements of the mesh when tested in accordance with Clause no. 1502 (6) shall be as shown in Table 15.5

Table 15.5 –Minimum Strength Requirements of Mesh and Connections

Mesh Type	10 x 12			8 x 10		6 x 8	
Characteristics	Zn	Zn	Zn + PVC	Zn	Zn + PVC	Zn	Zn +PVC
Mesh Wire Dia. (mm)	2.7	3.0	2.7	3.0	2.7	2.2	NA
Parallel to twist (kN/m)	36.0	46.0	36.0	55.	45.	36	
Perpendicular to twist (kN/m)	18	22	18	26	20	18	
Selvedge Strength (kN/m)	18	20	18	20	18	11	
Panel to Panel Connection using lacing wire or fasteners (kN/m)	10	11	10	20	16	11	
Punch Test (kN)	20	22	20	27	22	20	

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(5) Physical Properties

(a) Mass and adhesion of Zinc Coating

The coating weights shall conform to the requirements of NS: 163/ IS: 4826 Heavily Coated and soft type as shown in Table 15.6. The zinc coating shall remain adherent to the steel wire and confirm to such that zinc coating does not flake off, nor crack to such an extent that there is possibility of removing any zinc by rubbing with bare fingers.

Table 15.6 Minimum Mass of Zinc Coating and Permitted tolerances on galvanized steel wire diameters

Nominal Diameter of Galvanized wire, mm	Mass of Zinc coating, g/m^2	Permitted tolerances (+/-) on wire diameters ,mm
2.00	240	0.05
2.20	240	0.06
2.40	260	0.06
2.70	260	0.07
3.00	270	0.08
3.40	270	0.09
3.90	280	0.10

Uniformity*:* The coating on the wire shall be reasonably uniform as judged by the copper sulphate solution dip test. Number of dips shall be as per the table below:

Table 15.7 Uniformity of zinc coating:

Diameter of wire (mm)		2.00	2.20	2.40	2.70	3.00	3.40	3.90
Uniformity Test	Nos. of dips (each dip of 1 minute duration)	3	3	3	3	3	3	3
	Nos. of dips (each dip of 1/2 minute duration)	-	-	-	1	1	1	1

Adhesion*:* The adhesion of the zinc coating shall be such that, when the wire is wrapped six turns around a mandrel of 4 times the diameter of the wire, it does not flake or crack to such an extent that any flakes of zinc can be removed by rubbing with the bare fingers.

Tensile Strength

The tensile strength of wire used for double-twisted mesh, lacing wire, and stiffener, when tested shall be in accordance with the requirements of IS 280 for soft wire (350-550 MPa) at a minimum elongation of 10 percent, performed on a gauge length of test specimen as 200 mm.

(b) PVC (Polyvinyl Chloride) Coating

The initial properties of PVC coating material shall have a demonstrated ability to conform to the following requirements

Specific Gravity

In the range from 1.30 to 1.35 when tested in accordance with Test Method IS 13360: Part 3: Sec 1.

Tensile Strength

Not less than 20.6 MPa when tested in accordance with Test Method IS: 13360: Part 5: Sec 1

Hardness

Shore “D” between 50 and 60, when tested in accordance with Test Method IS: 13360: Part 5: Sec 11

(6) Test and standard of acceptance

Tensile Strength of Wire Mesh Panel– The wire mesh specimens shall be representative of proper field construction as to materials, mesh geometry, and workmanship, and shall be as large as practical to minimize the effect of variations. The tests shall be run with the load applied parallel to the axis of the twist and repeated on a separate test specimen with the load applied perpendicular to the axis of the twist.

The mesh shall be placed into the machine grips such that the gripped mesh will be maintained in the mesh geometry characteristic of field use. The specimen of approximately 0.8m width and 0.5m height shall be tested. The effective width to be considered for test specimen shall be the distance between two extreme gripping points. The specimen should extend by at least one mesh repetition beyond the extreme gripping points on either side. However, specimen should not extend more than two mesh repetitions beyond extreme gripping points. The mesh shall be pre-loaded to 10% of the specified minimum strength and machine head travel stopped. The mesh gauge dimensions shall be recorded at this time and taken as the initial dimensions of the specimen where such dimensions are required. If the sample slips at any of the gripping point during the test, such a test shall be discarded and a new sample shall be taken. The loading shall then continue uniformly maintaining the displacement rate of 75 to 100mm per minute until first fracture or unwrapping of an individual wire in the system occurs. The distortion of the mesh or changes in gauge length shall be measured to accuracy consistent with reporting the percent elongation to the nearest 0.5 %.

Pull-Apart Resistance Test*:* Where Pull-aprt resistance test is specified, the test procedure for performing the pull-apart resistance test shall be in accordance with the test procedure as per Clause 13.1.2 of ASTM A975-11.

Metallic Coating Weight – Perform coating weight tests and adhesion tests shall be performed in conformity with IS: 4826.

PVC Coating- The thickness and other parameter of the PVC coating shall be measured in accordance with IS: 16014.

(7) Construction

(a) General Requirements

Clause 1501 (3) shall apply

(b) Preparation of Foundation and surface bedding

Clause 1501 (3) (a) shall apply

(c) Arrangements of Joints

Clause 1501 (3) (b) shall apply

(d) Assembly

Clause 1501 (3) (c) shall apply

(e) Filling

Clause 1501 (3) (d) shall apply

(f) Securing Lids

Clause 1501 (3) (e) shall apply

(8) Measurement

Mechanically woven Gabion wire mesh and mattresses shall be measured in sq. meter. The boxes and mattresses shall be physically measured and be verified with their tolerances.

Stone filling in gabions including fixing of gabion in position, tying with binding wires and tension wires as

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specified shall be measured in cu.m.

(9) Payment

Mechanically woven Gabion wire mesh, gabion mattresses, stone filling shall be paid as per respective contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115 to complete the work in accordance with these Specifications.

1503 GEOSYNTHETICS FOR WORKS

(1) Scope

The specification covers the various applications of geosynthetics materials for use in river training works including supplying and laying as per contract specifications.

(2) Terminology

Geosynthetic is a general classification for all synthetic materials used in geotechnical engineering application. It includes geotextile, geogrids, ego-trips, geomembrane, geonets, geocomposites, geocells etc. Textiles made from natural fibers such as jute, and coir referred to herein under natural Geotextiles may also be used in different geotechnical engineering applications.

(a) Geotextile:

Any permeable synthetic textile used with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of a human-made project, structure, or system.

The geotextile fabric shall be a woven or non-woven or knitted fabric consisting of long-chain polymeric filaments or yarns such as polypropylene, polyethylene or polyester or any combination thereof, formed into a stable network such that the filaments or yarns retain their relative position to each other.

There are several application areas for Geotextile requiring specific functions namely separation, filtration, drainage, reinforcement, protection or a combination thereof.

(b) Geogrids:

A deformed or non-deformed netlike polymeric material used with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of human-made project, structure, or system.

Geogrids have relatively high strength, high modulus, and low-creep-sensitive polymers with apertures varying from 10 to 100 mm in size or more. The openings/holes in geogrids are either elongated ellipse, near squares with rounded corners, squares or rectangles. Geogrids can be of uni-axial grid, bi-axial grid or three-dimensional grids. Geostrip is another form of Geogrid, which is used in reinforced soil structures. It is primarily made of synthetic material in strips and is made from high tenacity polyester yarn and contained in a suitable low density polyethylene sheath. These are used as reinforcement in flood protection embankments, dykes, and canal side slopes.

(c) Geomembrane:

An essentially impermeable membrane (liner or barrier) used with foundation, soil, rock, earth, or in any other geotechnical application as an integral part of human-made project, structure, or system, used to control fluid migration.

Geomembranes are mostly made from HDPE, LDPE, PVC or polyethylene sheets, which are duly protected from ultraviolet exposure by carbon black or any antioxidants and thermal stabilizers.

Geo-clay-liners are also, in most cases, considered as geo membrane due to their low permeability performances and can be typically used as an alternative to Polymeric Geo-membrane under specific circumstances. These are used for slope protection and increasing impervious floor length in hydraulic structure due to its impermeable nature. These are used as impervious seepage barriers, canal bed linings, and cut-off curtains in earthen flood bunds and waterlogged command areas.

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(d) Geonets:

Geonets are used in combination with other types of geosynthetics. These are usually formed by continuous polymeric ribs or filaments at acute angle to one another. When the ribs are opened relatively large-size apertures are formed in a net like configuration.

These are typically used in combination with other geosynthetic materials to form a composite material.

(e) Geocell:

It is a three-dimensional structure with interconnected cells. The geocells are made of polyester/polypropylene/high density polyethylene stabilized with carbon black. Geo cells are used for slope protection and retaining/ river training wall. Geocells may be used for soil containment purposes. Geocells are filled with local soil or with granular material in the specified thickness to hold the material and distribute the load.

(f) Geocomposite:

A manufactured material, which could be a combination of any two or more synthetic materials like Geotextile, geogrids, geomats, geonets and geomembrane etc., in laminated or composite form. One of the popular forms of geocomposite is Drainage Composite. Drainage Composites are formed by combining geotextile or geomembrane with a core of geonet, geomat or seratted/corrugated polymeric materials.

(3) Marking

Geosynthetic rolls shall be marked with the following information:

(a) Manufacturer's name
(b) Roll number
(c) Grade
(d) Length
(e) Date of manufacture; and
(f) Product identification details

(4) Packing, Storage and Handling

(a) Each geosynthetic roll shall be wrapped with a material that will protect the geosynthetic from damage due to shipment, water, sunlight and contaminants. The protective wrapping with a tarpaulin or opaque plastic sheet shall be maintained during periods of shipment and storage.

During storage, geosynthetic rolls shall be elevated off the ground and adequately covered to protect from site construction damage, precipitation, prolonged ultra-violet radiation including sunlight, chemicals that are strong acids or strong bases, flames including welding sparks, temperatures in excess of 71°C, and any other environmental condition that may damage the physical properties of the geosynthetic.

(b) If the outer layer of the geosynthetic is damaged or exposed to sunlight for a period beyond that is permitted the outermost wrap of the rolls shall be discarded, and only the remaining undamaged/unexposed material shall be used. If the geosynthetic rolls become wet, the waterproof cover shall be removed, the rolls shall be elevated off the ground and exposed to wind in order to dry the fabric. The paving fabric used with bitumen overlays shall be completely dry prior to installation.

(5) Testing and Acceptance

(a) Geosynthetic Materials Shall is Tested and Certified in the following Manner.

(i) The manufacturer shall have ISO or CE certification for manufacturing process and quality control.

(ii) The manufacturer shall provide manufacturer's test certificate for every lot supplied from the factory.

(iii) The supplier shall provide third party test reports from an independent laboratory with valid accreditation for all the test values in Manufacturer's test certificate.

(b) Geosynthetic shall be tested in accordance with tests prescribed by BIS. In absence of NS codes, tests prescribed either by IS, ASTM, EN, or ISO shall be conducted.

(c) The material shall meet the requirements as specified in the contract.

1504 GEOTEXTILES FOR FILTRATION AND DRAINAGE

(1) Scope

The work covers the use of geotextile materials for drainage, filtration and erosion control works including supplying and laying as per design, drawing and these specifications. For drainage/filtration function, geotextile shall be able to convey water across the plane of the fabric throughout its design life. For separation function the geotextile shall prevent intermixing of two layers of dissimilar materials, throughout the design life of the structure. The geotextile as a filter material below erosion control measures like stone pitching or stone filled mattresses over the slopes, shall allow the water to flow out and at the same time prevent the loss of soil under the protective measures.

(2) Material

(a) Strength Requirement

The minimum strength of geotextile in terms of MARV under different installation conditions shall be as specified in Table 15.8

Table: 15. 8: Minimum Geotextile Strength Property Requirements

Installation condition	Type	Strength Property Requirement (MARV)							
		Grab Strength in Newton (N) as per IS: 13162 Part 5		Tear Strength in Newton (N) as per IS: 14293		Puncture Strength in Newton(N) as per IS: 13162 Part 4		Burst Strength in Newton (N) as per IS: 1966	
		Elongation at Failure							
		<50%	>50%	<50%	>50%	<50%	>50%	<50%	>50%
Harsh installation condition	Type I	1400	900	500	350	500	350	3500	1700
Moderate Installation condition	Type II	1100	700	400	250	400	250	2700	1300
Less Severe Installation condition	Type III	800	500	300	180	300	180	2100	950

Note:

(1) All numeric values in the above table represent Minimum Average Roll Value (MARV) in weaker principal direction. The MARV is derived statistically as the average value minus two standard deviations.

(2) When the Geotextile are joined together by field sewing, the seam strength shall be at least 60 percent of the material's tensile strength. All field seams shall be sewn with thread as strong as the material in the fabric.

(3) The puncture strength if determined in accordance with ASTM D 6241, the minimum requirement in terms of "Newton (N)" shall be as follows:

The Installation condition	Strength property requirement (MARV)	
	Puncture Strength in Newton (N) as per ASTM D 6241.	
	Elongation at Failure	
	< 50 %	> 50 %
Harsh installation condition	2800	2000
Moderate Installation condition	2250	1400
Less Severe Installation condition	1700	1000

(b) Ultraviolet Stability Requirements

The material shall satisfy the ultraviolet stability requirements specified in Table: 15.9.

Table: 15.9: Requirements for Ultra Violet Stability

S.No	Properties of Fabric	Requirements (Retained Strength)
1	Grab Strength	Not less than 70% after 500 hours of exposure
2	Tear Strength	
3	Puncture Strength	
4	Burst Strength	

(c) Hydraulic Requirements for various applications

(i) Subsurface Drainage and filtration

The geotextile shall conform to the physical requirements specified in Table 15.10.

Table: 15.10: Geotextile Requirements for Subsurface Drainage

In-situ passing 0.075 mm sieve (%)	Permittivity, per sec, as per ASTM D 4491/ IS 14324 : 1995	Maximum Apparent opening size, mm ASTM D 4751/IS 14294 : 1995
< 15	0.5	0.43
15 to 50	0.2	0.25
> 50	0.1	0.22

The type of geotextile shall be decided by the Engineer depending upon the installation conditions.

(ii) Separation

The geotextile for different subgrade soil conditions shall conform to the requirements given in Tables 15.11 and 15.12

Table: 15.11: Geotextile Requirements for Separation (Subgrade Soaked CBR >3)

S. No.	Geotextile Property	Requirement
1.	Permittivity as per ASTM D 4491	0.02 sec^{-1} (per sec)
2.	Maximum Apparent Opening Size as per ASTM D 4751	0.60 mm

Table: 15.12: Geotextile Requirements for Separation (Subgrade Soaked CBR ≤3)

S. No.	Geotextile Property	Requirement
1.	Permittivity as per ASTM D 4491	0.05 sec^{-1} (per sec)
2.	Maximum Apparent Opening Size as per ASTM D4751	0.43

(iii) Erosion Control

The geotextile for erosion control shall conform to requirements given in Table 15.13.

Table: 15.13: Geotextile Requirements for Erosion Control

In-situ soil passing 0.075 mm sieve (%)	Permittivity, per sec ASTM D 4491	Maximum Apparent opening size, mm ASTM D 4751
<15	0.7	0.43
15 to 50	0.2	0.25
>50	0.1	0.22

(3) Construction

(a) General requirement

Exposure of Geotextile to the elements between lay down and cover shall be a maximum of 14 days to minimize damage potential.

In trenches, after placing the backfill material, the geotextile shall be folded over the top of the filter material to produce a minimum overlap of 300 mm for trenches greater than 300mm wide. In trenches less than 300 mm wide, the overlap shall be equal to the width of the trench. The geotextile shall then be covered with the subsequent course.

Overlap at roll ends and at adjacent sheets shall be a minimum of 450 mm, except when placed under water. In such instances, the overlap shall be a minimum of 1 m. Where seams are required in the longitudinal trench direction, they shall be joined by either sewing or overlapping. All seams and overlaps shall be subject to the approval of the Engineer.

Care shall be taken during installation so as to avoid any damage to the geotextile. Damages, if any, during installation shall be repaired by placing a geotextile patch over the damaged area and extending it 1m beyond the perimeter of the tear or damage, or as approved by the Engineer.

(b) Subsurface Drainage:

Construction shall conform to these specifications.

(c) Separation

Where geotextiles are laid over soft foundation subgrades beneath flood embankments, canal prisms, or inspection access tracks road construction if required, Geotextiles shall be used as separation membrane. After preparation of subgrade as per the specifications along the road alignment, geotextile shall be rolled out as indicated in the drawings. The entire roll shall be placed on the subgrade and unrolled as smoothly as possible. Wrinkles and folds in the fabric shall be removed by stretching as required.

Adjacent rolls of Geotextile shall be overlapped, sewn, or joined as required. For curves, the geotextile shall be folded or cut and overlapped in the direction of construction. Folds in the geotextile shall be stapled or pinned approximately 0.6 m centre-to-centre. Before covering, the condition of the geotextile shall be checked for damage (i.e., holes, nips, tears, etc) by the Engineer.

Before placing the first lift of granular sub-base on the geotextile, a trial stretch of 100 m shall be laid as per roll width to establish a proper construction methodology of placing and compacting the sub-base in a manner that no damages are caused to the separation layer of geotextile.

(d) Filter Layer under Stone Pitching for Erosion Control

The geotextile shall be placed in intimate contact of soil ensuring slight tension, to avoid wrinkles or folds and shall be anchored on a properly shaped surface as indicated in drawings and approved by the Engineer. It shall be ensured that the placement of the overlying material be placed in such a manner that it does not tear/puncture the geotextile. Anchoring of the terminal ends of the geotextile shall be accomplished as per drawings through the use of key trenches or aprons at the crest and toe of slope as required. The geotextile shall be placed with the machine direction parallel to the direction of water flow. Adjacent geotextile sheets shall be joined by either sewing or overlapping. The pitching shall begin at the

toe and proceed up the slope. Big sized boulders shall not be allowed to roll down the slope.

Any geotextile damaged shall be either replaced or repaired with a patch, as directed by the Engineer, at the cost of the contractor.

(4) Measurement

The geotextile shall be measured in square metres as per planned dimensions with no allowance for overlapping at transverse and longitudinal joints. Excavation, back fill, bedding and cover material shall be measured separately as per relevant Clauses of the Contract.

(5) Payment

Geotextile shall be paid at the respective contract unit rate which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1505 GEOGRID

(1) Scope

The work covers the use of geogrids in erosion control of slopes, reinforced soil slopes and reinforced soil walls including supplying and laying as per design, drawing and these specifications. The use of geogrids as a component for reinforced soil slopes and walls shall be as per contract and instruction of Engineer.

(2) Materials

(a) General

Geogrids shall be either made from high tenacity polyester yarn jointed at cross points by weaving or knitting or thermal bonding process with appropriate coating or from polypropylene or polyethylene or any other suitable polymeric material by an appropriate process. Geogrids manufactured by extrusion process are integrally jointed, mono or bi-directionally oriented or stretched meshes, in square, rectangular, hexagonal or oval mesh form. The geogrids manufactured by weaving/knitting/bonding process shall be formed into a stable network such that ribs, filaments or yarns retain their dimensional stability relative to each other including selvages.

(b) Erosion Control

The Geogrid for erosion control application shall have the minimum tensile strength of 4kN/m, when tested as per ASTM D5035 (Minimum Average Roll Value in Machine Direction). The aperture opening size shall be minimum 20mm x 20mm and average grid thickness shall be minimum 1.0 mm. Geogrid for erosion control application shall be UV stabilized. The Geogrid shall have ultraviolet stability of 70 percent after 500hrs exposure as per ASTM D 4355.

(c) Reinforced Soil Slopes and Walls

The strength and other requirements shall be as specified in contract.

(3) Installation and Construction Operations

(a) Erosion Control

The Geogrid for erosion control applications shall be installed in accordance with the manufacturer's recommendation.

(b) Reinforced Slopes and Walls

The Geogrid for reinforced slopes and walls shall be installed in accordance with the manufacturer's recommendation.

(4) Measurement

The Geogrid shall be measured in square metres as per planned dimensions with no allowance for overlapping at joints, anchoring at toe and crest of the slope. Excavation, back fill, bedding and cover material shall be measured separately as per relevant Clauses of the Specifications.

(5) Payment

Geogrid shall be paid at the respective contract unit rate which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1506 GEOCELL FOR SLOPE PROTECTION

(1) Scope

The work covers the use of geocells for erosion control of soil slope including supplying and laying as per design, drawings and these specifications. Geocells filled with local soil or with granular material shall be placed on cut or fill slope to hold top cover soil and allow vegetation to grow.

(2) Materials

The geocell is a three-dimensional structure consisting of series of cells and resembles a honey combed structure. The geocell shall be made of a suitable polymeric material such as high-density polyethylene stabilized with carbon black or nonwoven geotextile.

(a) Strength and Other Requirements of Geocell

Geocell shall meet the minimum specifications and properties specified in Table 15.14.

The geocells for erosion control measures shall have cells with nominal opening of 450 cm2 to 1250 cm2 and perforations in the cell wall shall be between 11% to 16%. The cell depth for erosion control shall vary from 75 mm to 100 mm. Geocell made from nonwoven geotextile shall meet following specifications.

For anchoring the cells on steep slopes suitable arrangements shall be made as shown on the drawings.

(3) Installation and Construction Operations

Prior to laying of geocell on the slope, the surface shall be properly prepared, clean and dressed to the specified lines and levels as shown on the drawings.

Table: 15.14: Requirements of Geocell for Slope Protection

Property	Test method	Unit	Min. Required Value
Density	ASTM D1505	gm/cm^3	0.900
Environmental Stress crack resistance (ESCR)	ASTM D1693	Hrs.	3000
Carbon Black Content		% by Weight	1.5 to 2
Strip / Cell Wall thickness	ASTM D5199	Mm	1.20
Seam Peel-Strength Test		N per 25mm of cell depth.	350
Creep Rupture Strength	ASTM D2990	Creep Rupture Load at 10,000 hours shall be 1 kN minimum obtained from the 95% prediction interval at 10,000 hours considering a logarithmic time/creep rupture model.	

Trench keys along the crest and at the bottom of slope area shall be dug to fix the cellular system in the ground.

Cellular section shall be expanded to the predesigned shape and size and placed over prepared slope. Geocell sections shall be fastened together using accessories as per manufacturer's installation guide and the drawings.

After cellular sections are secured to the slope, the cells shall be filled with the specified materials ensuring that no damage is caused to the cells. Filling of cells shall be done from the toe of slope to crest of slope.

The fill shall be overfilled between 25mm to 50mm, and material shall be suitably tamped to leave soil flush with top edge of cell walls.

Once the soil filling is completed, turfing/ seeding shall be done as recommended.

(4) Measurement

The geocell protection work shall be measured as finished work in square meters as per planned dimensions with no allowance for overlapping at joints, anchoring at toe and crest of the slope.

(5) Payment

Geocell shall be paid at the respective contract unit rate, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

Unless stated otherwise, the rate specified shall also include turfing, seeding and all other incidental items to cover the work of vegetation on slopes. The quantities of cellular system for erosion control as shown on the drawings may be increased or decreased at the direction of the Engineer based on construction procedure and actual site conditions that occur during construction of the project. Such variations in quantity will not be considered as alterations in the details of construction or a change in the character of the work.

1507 GEOMEMBRANE

(1) Scope

The work covers the use of geomembrane materials for slope protection and impervious lining construction works, including supplying and laying as per design, drawings, and these specifications. Geomembrane shall be able to control water seepage across the plane of the fabric throughout its design life. For impervious lining construction, the geomembrane shall prevent seepage of water from the lined structure throughout the design life of the structure.

(2) Materials

Geomembranes are mostly made from HDPE, LDPE, PVC or polyethylene sheets, which are duly protected from ultraviolet exposure by carbon black or any antioxidants and thermal stabilizers. The PVC geo-membrane shall be suitably manufactured from vinyl chloride resin homo polymer. Water soluble compounding ingredients shall not be used. Plasticizers that are resistant to migration and bacterial growth shall be used. The PVC geo-membrane shall be pigmented to produce a uniform colour.

Geo-membrane shall be reasonably free from defects such as holes, tears or blisters. The edges shall be free of nicks and cuts visible to the naked eye. Geo-membrane shall be uniform in colour, texture and finish. The colour, unless specified, shall be black. Geo membranes shall be of various thickness ranging from 0.3mm to 1.5 mm and suitable thickness as specified in the contract or approved by the Engineer shall be selected for the use depending upon the site condition.

(a) Strength and Other Requirements of PVC Geomembrane

PVC Geomembrane shall meet the minimum specifications and properties specified in Table- 15.15. The PVC Geomembranes for slope protection measures shall have thickness ranging from 0.3mm to 1.5mm. Suitable thickness shall be used as per contract and/ or approval of the Engineer where decision shall be taken based on the requirement needed for specific site conditions. For anchoring the geomembrane on slopes suitable arrangements shall be made as shown on the drawings.

Table 15.15 Requirements of PVC geomembrane for slope protection

S.N.	Properties	Requirements	
		Minimum	Maximum
1	Thickness (mm)	0.3	1.5
2	Specific Gravity	1.3	1.4
3	Tensile strength, kg/cm^2	115	150
4	Elongation at break, percent	250	
5	Tear strength, kg/cm		
	Warp	18	40
	Weft	20	55
6	Puncture resistance, kg	4	13
7	Hydrostatic resistance, kg/cm^2	2.5	10

Source: IS 15909: 2010 (Indian Standard PVC Geo-Membranes Specification)

(3) Installation and Construction Operations

Prior to laying of geomembrane on the slope, the surface shall be properly prepared, clean and dressed to the specified lines and levels as shown on the drawings. Trench keys along the crest and at the bottom of slope area shall be dug to fix the geomembrane in the ground.

Geomembrane shall be expanded to the predesigned shape and size, and placed over prepared slope. Geomembrane sections shall be fastened together using accessories as per manufacturer's installation guide and the drawings.

After Geomembrane sections are secured to the slope, it shall be covered with the specified materials ensuring that no damage is caused to the geomembrane. Placement of cover material shall be based on the types of cover material.

(a) Placement of Cement-based Covers

Cover materials shall be used as specified in the contract. Cement-based cover materials include prefabricated pavers or slabs, cast-in-place concrete, or compacted soil cement. A needle-punched nonwoven geotextile should be placed on a geomembrane prior to placing cement-based materials to protect the geomembrane and to enhance cover stability during construction.

(b) Placement of Granular Materials

Granular materials placed on geomembranes should be limited to a maximum particle size of 0.5 inch order to prevent damage or puncturing of the geomembrane.

During construction of the cover, particular care should be taken to prevent damage to the geomembrane. The cover material should never be pushed down the slope because the gravitational stresses may cause the geomembrane to come out of the anchor trench or cause the liner to tear. Equipment placing the cover material should not be driven directly on top of the geomembrane. When large trucks or scrapers are used to deliver cover soils, specific haul routes should be planned with temporarily increased soil cover (i.e., 3 to 6 feet depending on equipment size) to protect the underlying geomembrane.

As placement of a soil cover progresses, care should be taken to prevent wrinkles from developing at the leading edge of the soil. The geomembrane should be in intimate contact with the underlying subgrade and, if not, the wrinkles could fold over and be stressed at the apex, which could produce stress cracks over time, leading to excessive leakage.

(4) Measurement

The Geomembrane for slope protection work shall be measured as finished work in square meters as per planned dimensions with no allowance for overlapping at joints, anchoring at toe and crest of the slope.

(5) Payment

Geomembrane shall be paid at the respective contract unit rate which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1508 GEO - COMPOSITE DRAINS

(1) Scope

The work covers the use of geocomposite drainage system: (i) Fin drains and (ii) Prefabricated Vertical Drains. The work for fin drains shall be carried out in accordance with the requirements of these specifications and to the lines, grades, dimensions and other particulars shown on the drawings or as directed by the Engineer.

Fin drains with plastic core shall be installed for affecting vertical and/ or horizontal drainage.

Prefabricated vertical drains shall be installed in soft saturated subsoils at designed spacing so as to accelerate the rate of consolidation.

(2) Materials

(a) Fin drains or Geo-Composite or Drainage Composite

Fin drains shall be made of light weight, three-dimensional high compressive strength polyethylene cores; and heat bonded or needle punched polypropylene/polyester geotextile provided on one side or both sides of the core as per the requirements. Geotextile used in drainage composite shall meet the requirements as specified in Table 15.16. The properties of the core material shall meet the requirements as indicated in Table 15.17.

Table 15.16: Geotextile Requirements for Fin Drains

In-situ soil passing 0.075 mm sieve (%)	Permittivity, per sec ASTM D 4491/ IS 14324 - 1995	Maximum Apparent Opening Size, mm as per ASTM D 4751/IS 14294 - 1995
< 15	0.5	0.43
15 to 50	0.2	0.25
> 50	0.1	0.22

Table 15.17: Properties for Fin Drain Composite

Property		Test method	Units	Minimum Average Roll value
Tensile strength		EN ISO 10319	kN/m	16
CBR Puncture Resistance		EN ISO 12236	N	3000
Mass per unit area		EN ISO 9864	g/m2	650
Thickness of Composite		EN ISO 9863	mm	4.5
In-plane permeability	Hydraulic Gradient, i=1 at 100 kPa pressure	EN ISO 12958	l/m	0.55
	Hydraulic Gradient, i=1 at 200 kPa pressure			0.45

(b) Prefabricated Vertical Drains (PVDs)/ Band Drains

The PVDs/ Band Drains shall meet the requirements as specified in Table 15.18

Table: 15.18: Properties for Prefabricated Vertical Drains/ Band Drains

S. No	Property		Test Method	Value
A	Composite Drain			
1	Width			≥100 mm
2	Thickness		ASTM D5199	≥ 4 mm
3	Tensile strength		ASTM D4595	>2.00 kN
4	Elongation at break			>35 %
5	Discharge capacity	i = 1.0 at, 300 kPa pressure	ASTM D4716	>1.5 x 10^{-5} m^3/s
B	Core			
1	Material			Polypropylene/ Polyethylene
2	Configuration / structure			Corrugated, filament, dimpled, studded etc.
C	Filter			
1	Material			Polyester/ polypropylene
2	Structure			Nonwoven
3	Mass per unit area		ASTM D5261	>120 g/m^2
4	Tensile strength		ASTM D4632	>500 N
5	Elongation at break			>45 %
6	Trapezoid tear strength		ASTM D4533	>150 N
7	Permeability		ASTM D4491	>5 x 10^{-6} m/s
8	Apparent opening size		ASTM D4751	

(3) Installation

(a) Fin Drains or Geo-Composite or Drainage Composite

The installation of fin drains shall be as per drawings. Where fin drains are assembled on site, the assembly area shall be clean and dry. No geotextile or core material shall be exposed to daylight (or any source of ultraviolet radiation) for a period exceeding 50 hours. Where fin drains are laid in a trench, the bottom of the trench shall be free of irregularities and shall be brought to the required level. Rock and other hard protrusions shall be removed and any excess cut in the trench bottom shall be filled and compacted back to the required grade with suitable excavated or imported material as directed by the Engineer. Fin drains shall be capable of being connected longitudinally or laterally into pipe systems or chambers for inflow and outflow purposes. Joints parallel to the direction of flow, and any exposed edge shall be protected from the ingress of soil by a geotextile wrapping with a minimum overlap of 150 mm or other measures as approved by the Engineer. The splicing of lengths of geotextile and minimum overlap shall be as per the drawing or as approved by the Engineer.

(b) Prefabricated Vertical Drains (PVD)

The installations for PVD shall be as per relevant Clauses of specification.

(4) Measurement

Measurement for Fin drain shall be in running meter of its length used in trenches. Measurement of Fin drain shall be in Sqm when used behind retaining wall, below canal lining, below pavement, chimney drain etc. Measurement for payment for PVDs shall be as per specification Clause for drain.

(5) Payment

Fin drain shall be paid at the respective contract unit rate which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 1506 in addition to those specified in Clause 115.

1509 SOIL NAILING SYSTEM (WITH SEMI-FLEXIBLE 3D GALVANIZED STEEL MAT) FOR SLOPE PROTECTION

(1) Scope

The soil nailing system with semi-flexible 3D galvanized steel mat is a high-quality construction system consisting of a 3D zinc-coated steel grid mat, steel cables, zinc-coated distribution bars, injection bore nails, anchors or T-steel nails of different lengths, and the necessary fastening elements such as binding loops and cable clamps. It can be used in four different ways in slopes, embankments, and river control works.

a) Slope stabilization and protection works as a semi-flexible soil nailing system, with or without vegetation.

b) Slope and riverbank erosion control as revetment, with or without vegetation.

c) Riverbed erosion control in drainages, check dams, and causeways.

d) As a reinforcement element for embankment and earthwork surfaces.

(2) Materials /General requirements

In order that the structure can fulfill its task, minimum requirements regarding the material and dimensional accuracy must be met upon installing the soil nailing system with *semi flexible 3D-steel Mat*. A careful installation of the system allows repairing of deformed/damaged slope parts, improves and protects the general slope stability and allows enduring and permanent greening of the slope.

The contractor is exclusively responsible for observing the minimum installation requirements. No other parts than the prescribed components for **Soil Nailing System with Semi-Flexible 3D Galvanized Steel Mat** must be used. For detail construction guidelines of manufacturers "**Soil Nailing System with Semi-Flexible 3D Galvanized Steel Mat"** shall be referred. In the event of deviations from instructions, the Contractor shall bear the whole responsibility of the work performed.

The soil nail system with 3D semi-flexible galvanized steel mat generally comprised of the following materials:

(a) Construction Elements:

3 D galvanized steel panels: The size of the 3D panels varies in length and width: length 2850 – 3200 mm width 1100 – 1200 mm. The height of panel will be 80 mm. A staple of 100 panels (approx. 384 m²) will be stapled on one wooden pallet. This profile is made of at least 275 g/m² zinc coated steel sheet band of thickness between 1.5 – 1.6 mm.

(i) **T-section steel nail**: Special designed earth nail made out of steel (T-section profile), size varies from 25/25/3 mm up to 40/40/5 mm with a sharp taper at one end and one hook made out of a round bar ø12 or 16 mm at the other end is used to fix the 3D panels. This nail shall be galvanized to protect it from corrosion. The zinc coating on T-steel nails must be at least 235g/m². The T-steel nails shall have lengths from 0.60m to 3.50 m as required.

3D- Panels



T-Section steel nail



(ii) **GEWI nail system:** If the T-section steel nails are not sufficient to provide required level of safety, bored GEWI nails of 28 mm diameter may use to secure the 3D mats.

The GEWI Thread bar System consists of high yield GEWI® screw able steel and corresponding

coupling and anchoring accessories, which enable safe and easy connections between anchorages made of GEWI® steel, in accordance with the German approvals Z-1.5-76, Z-1.5-149 and Z-1.5-2.

GEWI Steel High Yield Thread bar is a high tensile alloy steel bar which features a coarse left-hand thread over its full length. The system has proved its efficiency around the world and offers versatility in a range of applications. Manufactured in accordance with the German Certificate of Approval issued by the Deutsches Institut für Bautechnik, the system also offers general conformance with BS 4449: 2005 (Carbon Steel Bars for Reinforcing of Concrete).The minimum specified characteristic yield strength is 500 N/mm2 for bar diameters 16 - 50 mm. These bars can be used in soil nailing at varying lengths between 4m to 8m, but in special situation it can be extended to any design length using special coupling socket connections. 16 - 50 mm bars can also be welded using appropriate industry practices relative to the carbon content of the steel.



GEWI Thread bar (used as nails) and different types of nuts and specially designed PVC spacer for fixing 3D mats

A borehole of 90 mm shall be bored up to the designed length (usually up to 8m) and GEWI bar is inserted and cement grout is filled into this hole and nail is fixed in its position. Centralizers (spacer) made from PVC are available for all hole diameters and nail configurations. Appropriate spacer of other materials can also be used as directed by site engineer.

Cement Grout for Filling of the Boreholes in case of GEWI nails

The source materials for the grout are cements with special properties in accordance with DIN 1164-101 and the water in accordance with DIN EN 10085, and (if necessary) additives in accordance with DIN EN 934-26 and aggregates with maximum 4 mm grain diameter in accordance with DIN EN 126209. The water/cement ratio must be between 0.35 and 0.50; in particular in cohesive soils the lowest possible ratio shall be chosen. The cement aggregate mix ratio can be varied from 1:1/2 to 1:1. The cement grout must be mixed mechanically and must not segregate and lump before it is injected. The minimum compressive strength (28 days) of the grout must be 40 N/mm².

(iii) **Distribution rod and rope clip connector:** Distribution bar made of high tensile steel, ø10-12 mm, and length 3700 mm and wire rope clip DIN 741 are used to interconnect the 3D panels and T-Nails. The steel bar is also galvanized to protect it from corrosion. The minimum zinc coating on distribution bars must at least 235g/m². The cable clamps according to DIN 741 and DIN 1142 are used for connecting the distributor rods with each other. Horizontal joints are fastened with two clamps. The connection of a diagonal rod, if any, with a horizontal rod requires only one clamp.

(iv) **Connecting elements:** If slope stabilization requires longer, static load-bearing soil nails (bored GEWI nails), soil nails are connected with 12mm dia. steel ropes via specially designed connecting elements and cable clamps. These elements are basically Type 100/166-15/80 ER 16 – 30°and Type 100/232- 15/80-DR 16-30° and wire rope clip according to **DIN 1142.**

(v) **Wire rope:** 12mm dia galvanized steel wire rope is used to connect the GEWI nail heads and fasten the 3D mats. The minimum breaking load of such rope must be 90.7 kN. The galvanized wire rope

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(6x19 SE) must meet the requirements of EN12385-4. The weight per meter of such wire rope will be 0.498 kg.



Distribution bar and rope clip connector



Bundle of binding loops



Connecting elements

(b) Backfilling Materials:

(i) **Crushed stone aggregates**: After installation of the 3D panels, they are backfilled with angular material. This permits the creation of a good subsoil structure and hence a gripping layer for the subsequent humus backfill and draining of slope water below the humus layer. Sometimes, use of crushed limestone aggregates has a neutralizing impact on acid soils or in the event of acid precipitation. The crushed stone aggregates of size between 32 mm– 63 mm are preferred for backfill. Moreover, only angular material is appropriate, since round grain can roll out of the panels when filled in. For detailed material specifications please refer to construction guidelines for soil nailing systems with semi-flexible 3D mats. About 3-4 m^3 of crushed aggregates is required for a surface area of 100 m^2. The filling can be performed either by machine or manually.

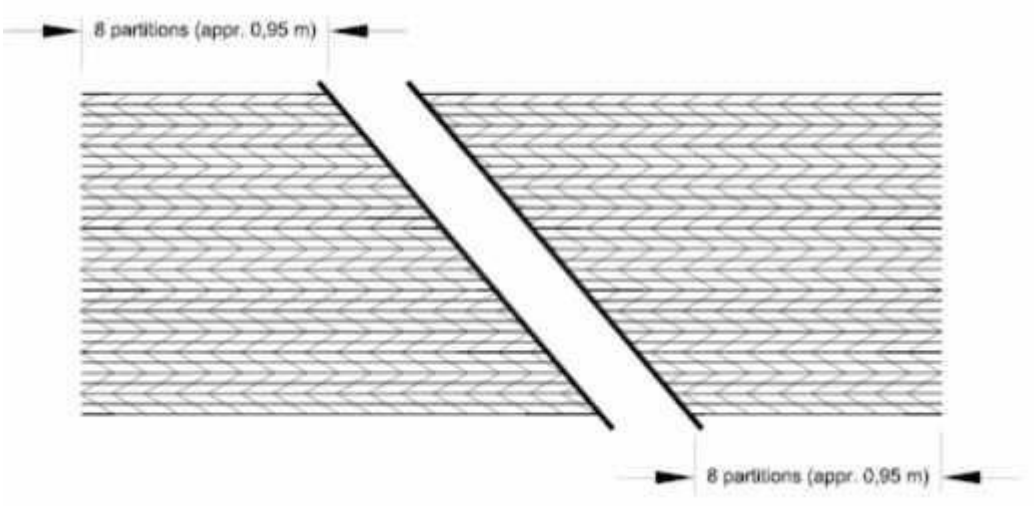
(ii) **Humus Material:** Depending upon the site and design of the slopes, humus material is used to make the slope green. Humus (topsoil) is a requirement for any permanent vegetation. Plants protect the slope against erosion. They extract moisture from the topsoil, prevent too fast runoff and the plant roots stabilize the topsoil. Once grown in, the vegetated surface can scarcely be distinguished from the surroundings. A material appropriate for the humus layer or topsoil shall have high humus content (5% at least) and a sufficient content of nutrients (nitrogen, phosphate and potassium). The soil can be blended with compost or manure, if required. In order to ensure long-term adherence of the material to the 3D grid panels, a clay content of 20% - 30% is recommended. For good gripping on steep slopes and increasing its water retention capability, the substrate can be blended with 1% - 2% bentonite. The spraying of humus can be done manually or by using machines. For details, please refer to construction guidelines.

(3) Construction procedure (for slope stabilization and erosion control on slope)

(a) Preparation of the slope: The slope shall be trimmed off and leveled. If the level difference between

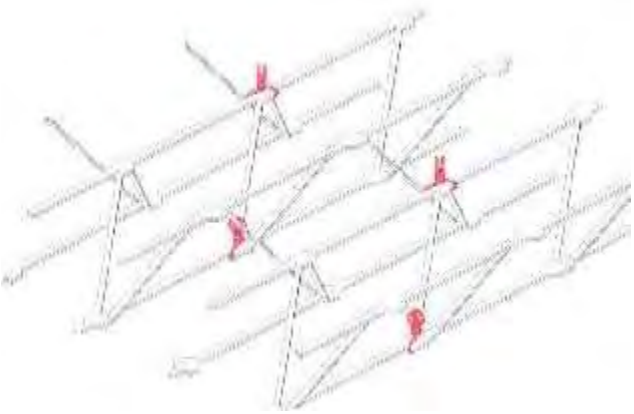
the lowest point of the removed part and the highest point of the existing slope is greater than 40 cm, the depression must be filled with draining capable material before installing the 3D panel. The slope to be stabilized must be cleared from debris until it is free from loose stones. In cases where depressions or trenches are deeper than 40 cm, it is highly recommended to install a separate layer of 3D panels before refilling. The edges of the removed part or unstable slope must be rounded off carefully in order to avoid flaws in the slope stabilization upon integration in the native soil.

(b) **Cutting the panels:** 3D panels are taken out from pallet and cut diagonally (see sketch below). Diagonal installation of semi-flexible 3D mat in soil nailing system requires that grid panels are cut in two pieces. Make sure that the 3 D panels always are laid on the ground with their arrow-knots-side down. For details see the construction guidelines.



Cutting of 3D panels

(c) **Installation of panels, connections and overlapping:** After cutting diagonally, the panels are installed from the bottom of the slope at an angle of about 40°-55°. Upon installing the grid panels, make sure that they overlap sufficiently. Overlapping must be 2 knots (approx. 250 mm). Ensure that the panels intermesh well when doing this. The two individual overlapping panels are connected with a wire loop on every 2nd cross knot and on every 2nd arrow knot. Panels must also overlap crosswise. Overlapping is ½ wave (approx. 40 mm; see drawing). For this, make sure that the panels intermesh well. One wire binding loop is required in every 3 knots while overlapping panels from sides.

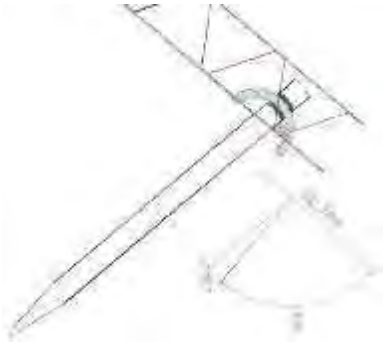


Binding with wire loops

(d) **Insertion of distribution bars:** In order to increase the adherence of the semi- flexible 3d mat into soil nailing system and to the subsoil, round steel distributor rods (usual lengths between 2500 – 3700 mm, Ø 10 – 12 mm) are pushed in the grid panel horizontally (and also diagonally if required), during the installation from the side which has not yet been finished. The intervals will be according to the existing nail grid (example: a nail grid of 1.5 m x 1.5 m requires that the rods are introduced in a vertical distance of 1.5 m measured on the slope). If 2500 mm rods are used, rods are pushed in if two widths are installed, if rods are 3700 mm long, they must be pushed in after 3 panel widths. Additional rods can be pushed diagonally in the 3-D steel panels. The spacing must be according to the construction guidelines or system supplier, or as instructed by site Engineer. The distributor rods are linked with each other with 2 cable clamps according to former

DIN 714 size 16. For this, make sure that the distributor rods overlap by at least 20 cm – 25 cm. For details refer to the construction guidelines. In case of static nails (bored GEWI Nails), steel wire rope is used instead of distribution bars.

(e) **Driving the nails (constructive fastening):** The T section galvanized steel earth nails are driven on the slope in a grid specified (based on the design) according to the local soil characteristics (e.g. consistency, water content, bearing capacity). This is done either manually with a heavy hammer, or mechanically with a pneumatic hammer equipped with an appropriate head extension. The individual soil nails should be driven in at a slight angle upwards to the soil surface (approx. 10° to a perpendicular axis laid on the slope) and hence put under tension. As a matter of principle, soil nails must be driven in underneath the distributor rods.



Inclination of T-steel nail

If nails cannot be driven in because of subsoil conditions, in case of solid rock or unconsolidated rock material, holes must be drilled for the nails. To do this, use a manual drilling machine or light weight drilling carriage to drill holes of 28 mm – 32 mm in diameter for nails made out of T 25/25/3.5 mm and 48 – 52 mm in diameter for nails made out of T 35/35/4.5 mm. These holes are grouted with cement mortar (water/mortar ratio ≤ 0.45) and the soil nail is stuck in the grouted hole. If the subsoil allows it, it is recommend drilling holes approx. 20 cm less deep than the length of the soil nail, and to drive the nail in the remaining length. In this way the nail holds tight immediately in the subsoil and stability and density of the cement mortar are improved. Alternatively, depending upon sub-soil conditions, T- sections nails can also be directly hammered into pre-bored holes of slightly lesser diameter (approx. 5mm less) than the size of T-nails without using any cement grout. In such situation pull-out test of T-nails may be necessary to estimate the desired pull-out resistance of system nails.

(f) **Soil Nailing System with Semi-Flexible 3D Galvanized Steel Mat in combination with static load bearing soil nails (GEWI-Steel nails):**

If Soil Nailing system with Semi-Flexible 3D Galvanized Steel Mat is used in combination with static load bearing soil nails the 3 D steel panels are connected with round bar anchor bolts or injection grouting nails using special designed connecting elements and wire ropes. After installing (drilling and grouting) the soil nails, first of all, 3D panels are placed on the slope and stuck over the free ends of the soil nails. Then the upper girdles of the 3 D steel panels are cut in a radius of 10 cm around the soil nail head. The connecting element is put on the soil nail head in such a way that it finally lies on the level of the upper girdles of the steel grid.

Following the grid of the soil nails steel cables are installed over the upper girdles of the 3 D panels horizontally (and diagonally if required). The wire ropes are used to distribute the load from the 3 D panels to the soil nails. To get a force locking connection the wire ropes are threaded in the shackle of the connecting element. The cables are clamped with one clamp at every second connecting element.

Then the wire ropes are fixed at one end and pre-stressed by pulling them by hand at the free end. The wire ropes are fastened at both ends making a rope sling with 3 pieces of wire rope clips.

Then the nuts of the soil nails are screwed on and tightened. One may adjust the stress and the ratio of arch of the wire ropes defined in the stability analysis by screwing down the nuts tightly or loosely into the 3 D panels.

(g) **Filling with angular material:** After installation of the 3 D panels, they are backfilled with angular material. This permits the creation of a good subsoil structure and hence a gripping layer for the

subsequent humus backfill and draining of slope water below the humus layer. The crushed stone aggregates of size between 32 mm – 63 mm are preferred for backfill. Fillings can be done either manually or by using machines. Filling is generally done from bottom to top and it shall be made as compact as possible.

(h) **Spray of humus/Top soil:** Depending upon the site and design of the slopes, humus material can be used to make the slope green. The spraying of humus can be done manually or by using machines. A material appropriate for the humus layer or topsoil with high humus content (5% at least) and a sufficient content of nutrients (nitrogen, phosphate and potassium) can be used on the top of gravel layer to ease the growth of plants. The topsoil can be blended with compost, grass seeds or manure, if required. In order to ensure long-term adherence of the material to the 3D grid panels, a clay content of at least 20% -30% is recommended. For good gripping on steep slopes and increasing its water retention capability, the substrate can be blended with 1% - 2 % bentonite. For details about the humus spray machine please refer to construction guidelines.

(i) **Draining measures on slopes:** If the slope to be stabilized contains ground water, draining measures must be planned. There are two options for installation of a drainage system using 3D galvanized steel mats:

(i) **Drainage without reinforcement**. In flat slopes (up to 45°), drainages can be installed without reinforcement with the 3-D panels. Dig ditches of at least 40 cm depth (maximum depth approx. 80 cm) and fill them with angular material. Arrange ditches in a Y-form down the slope. All earthen sides of the draining ditches must be covered with a non-woven fabric (Geotextile), in order to inhibit fine grains from penetrating into the drain. The sidewalls of the ditch can be provided with a steep slope of up to 90° according to the stability of the surrounding soil. The draining ditches must be filled before installing the 3D grid on the slope surface to avoid the crumbling of edges and entering the fine grains from the surrounding soil which may clog the draining system.

(ii) **Drainage with reinforcement consisting of 3-D panels:** On slopes of an angle greater than 45° there will be a risk of sliding the draining ditch as a whole. This can be avoided by installing the 3D panels on the ditch. For this, the panels are bent up lengthwise according to the ditch dimensions in such a manner that open rectangles form (cross-section formed like a U), and they are then tied up and secured into the ground. Where the depth of ditch is greater than 80 cm and the angle of the slope greater than 55°, the installation of two reinforcing layers (double layer of 3D panels) is recommended. The 3 D panels are fixed in the draining ditch using distributor rods and T – Steel earth nails. To determine the amount of nails to fix the 3D panels inside a draining ditch calculate for a ditch 60cm width approx. 3 pcs of nails per layer for 3 m of drainage length and 4 pcs of nails per layer for a ditch of 1.20 m width per 3 m length. The draining ditch is then filled with the corresponding coarse materials (grain size between 32 and 60 mm). The ditches must be covered with a filter-stable non-woven geo-textile on all earthen sides, in order to avoid penetration of fine-grain earth material. It is recommended to clamp the non-woven geotextile directly on the drainage base and then to put the entire construction of 3D panels into the ditch and fill it up with recommended aggregates. For details of ditch construction on slopes refer to the construction guidelines for soil nailing with semi-flexible 3d mat system.

(4) Construction procedure (for riverbank and riverbed erosion stabilization, road pavements)

(a) The basic installation procedure of the soil nailing system with semi-flexible 3d galvanized steel mat is same as in case of slope stabilization and erosion control on slopes. But in case of riverbank and riverbed erosion control, it is recommended to use appropriate geotextile on the base of the slope/riverbed based on the velocity of flow and river water current.

(b) It is also recommended to calculate the hydraulic safety (uplift and pull out) of the soil nailing system with semi-flexible 3d galvanized steel mat on the riverbank or on riverbeds (such as launching apron). The nails used to anchor the system must be strong enough to resist the uplift force and pull out from

high turbulent velocity during high flood situations.

(c) Since the angular material inside the 3D panels are mechanically interlocked inside the system, this system (also in multi layers) can be used in riverbeds for making causeways, temporary diversions and river crossings for all kinds of vehicular traffic loads, which needs special design of this system.

(d) The soil nailing system with semi-flexible 3d galvanized steel mat can also be used as reinforcing elements in road pavement construction. It can be used in earthen roads, gravel roads and also in asphalt roads. All of these special constructions need to be designed separately depending upon the site conditions and Client's requirements. For any special design requirements, it is recommended to consult a design engineer who has experience of designing soil nailing with semi flexible 3D mats.

(5) Quality Control

The soil nailing system with semi-flexible 3d galvanized steel mat elements shall have the following requirements:

(a) 3D Panels

The 3D galvanized steel mats shall be made of high strength steel sheet with at least 275 g/m² zinc coating. The thickness shall be 1.5 – 1.6 mm, panel size width 1100 - 1200 mm, Length 2850 - 3200 mm, height 80 mm. The weight shall be approx. 3.0 kg/m² to 3.33 kg/m² or 10.8 kg/panel to 12.8 kg/panel corresponding to the thickness of sheet steel used (1.5 or 1. 6 mm). Approximate loading of Steel type S 350 GD model, for evenly distributed load if knots are fixed shall be 30 kN/m². The Maximum tensile strength of 3D panels lengthwise shall be at least 70 kN/m. The 3D Panels must be supplied by reliable and certified manufacturer.

(b) Other construction elements

The distribution bars, the T-section steel nails, steel ropes, rope clips and binding loops shall meet the entire requirement as mentioned in the specifications and meet all the requirements as mentioned in the construction guidelines "soil nailing with semi-flexible 3d mat system, Instructions for use" or shall be according to the test certificates provided by the recognized manufacturing companies. All of these accessories except 3D panels can be produced locally or procured from local markets but shall be tested for its strength requirements before use.

(c) Design of soil nailing system with semi-flexible 3D galvanized steel mat

Before implementing the soil nailing system semi-flexible 3D mat on a slope, the slope shall be designed to calculate the spacing and length of T-steel nails or special soil nails (GEWI nails). Slopes of similar nature can be constructed on the basis of typical designs prepared for particular road sections with similar soil properties. Based on the available soil data and slope geometry, the typical designs for different heights and slope angles can be prepared in advance.

Reliable finite element programs or appropriate software can be used in the analysis of soil nail system using semi-flexible 3D mat as facing elements. In case of special use of soil nailing system with semi-flexible 3d mat in riverbank erosion control, riverbed erosion control, causeway design or pavement construction, special designs by a certified geotechnical engineer is recommended.

(d) Construction and workmanship:

The construction of the soil nailing system using semi-flexible 3d mat must be in accordance with its construction guidelines. The spacing and length of installed soil nail should be as designed by the design Engineer. The spacing between two nails shall not exceed by 1.5 m and the minimum length of nail shall be at least 1 m in all situations where the underground material comprises of loose soil or rock material.

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(6) Measurement and Payment

(a) If the typical designs are used with known spacing and length of nails, the measurement of complete construction (whole system) can be done in square meter surface area of installed soil nailing system with semi-flexible 3d mat. Depending upon the easiness of construction, it can be divided into two types:

(i) Soil nailing system with semi-flexible 3d galvanized steel mat and T-section nails (1m, 1.5m, 2m, 2.5m, 3m or 3.5m) for slope < 45 ° in m²

(ii) Soil nailing system with semi-flexible 3d galvanized steel mat and T-section nails (1m, 1.5m, 2m, 2.5m, 3m and 3.5m) for slope > 45 ° in m²

Depending upon the use of Humus, it can be with or without humus spray, or humus spray can also be measured separately.

(b) If there is no typical design for the site, the type, spacing and length of the nails are unknown, then the measurement can be spilt into two: System installation in square meter and nail driving in running meter.

(i) Installation of Soil nailing system with semi-flexible 3d galvanized steel mat with distribution bar, binding, filling all complete (excluding driving of T- nails) for slope <45° in m²

(ii) Installation of Soil nailing system with semi-flexible 3d mat with distribution bar, binding, filling all complete (excluding driving of T-nails) for slope >45° in m²

(iii) Driving of T-nails in slope <45° in r-m

(iv) Driving of T-nails in slope >45° in r-m

(v) Driving of bored system (GEWI) nails with grouting in slope

Depending upon the soil/rock type, driving T-nails may need drilling the holes and use of cement mortars, thus different rates/ rate analysis shall be applicable.

1510 DRY BOULDER LAUNCHING AND SLOPE PROTECTION WORKS

(1) Big Boulder Pitching for Launching Apron

(a) Materials

Big Boulder /Stone used for Launching Apron for protection of Riverbanks against scour shall be of required size and weight as specified in the contract or on drawing and shall be from a quarry or arising from the excavation. The weight of the boulder to be used shall not be less than 40 kg or 200 kg as specified. The boulder/ stone shall be sound, hard, and free from cracks or other defects. The boulder/stones, when immersed in water for 24 hours, shall not absorb water by more than 5 percent of their dry weight when tested in accordance with IS: 1124. The specific gravity of boulder/stone shall not be less than 2.65.

(b) Construction

The laying of big boulder shall be done as indicated on the drawings. The thickness of launching apron shall be as shown on the Drawing. The boulders not less than 40 kg shall be laid for launching apron manually or using machines depending upon the nature of the river, its flow velocity and the condition of the working site as specified in the contract. The boulders weighing more than 200 kg shall be laid for launching apron using machines for big river with high velocity as specified in the contract. Before laying the boulder, the bed surface shall be made to the required profiles. Depressions shall be made even and thoroughly compacted to the extent possible. Stone/boulder shall be placed to the required length, thickness and depth as per the Drawing. The top surface of the launching apron shall be smooth as far as possible.

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(c) Tests and Standard of Acceptance

Stones/boulder shall be tested for water absorption and specific gravity and shall meet the specified criteria. One set of test (3 tests in a set) shall be carried out for every change in source of material and shall meet the specified criteria.

(2) Boulder Pitching for Slope Protection

(a) Materials

Boulder /Stone used for slope protection of riverbanks shall be of required size and weight as specified in the contract or on drawing and shall be from a quarry or arising from the excavation. The weight of the boulder to be used shall not be less than 40 kg as specified. The boulder/ stone shall be sound, hard, and free from cracks or other defects. The boulder/stones, when immersed in water for 24 hours, shall not absorb water by more than 5 percent of their dry weight when tested in accordance with IS: 1124. The specific gravity of boulder/stone shall not be less than 2.65.

(b) Construction

The laying of boulder over prepared filter media (Geotextile or graded gravel filter) shall be done as indicated on the drawings. The thickness of slope pitching shall be as shown on the Drawing. The boulders weighing not less than 40 kg shall be used for slope pitching manually depending upon the nature of the river, its flow velocity and the condition of the working site as specified in the contract. Before laying the boulder, the slope surface shall be made to the required profiles. Depressions shall be made even and thoroughly compacted. Filter media shall be properly laid on the prepared slope surface before laying boulder/stone. Stone/boulder shall be placed to the required length, thickness and depth over the filter media as per the Drawing. The top surface of the pitching shall be smooth as far as possible.

(c) Tests and Standard of Acceptance

Stones/boulder shall be tested for water absorption and specific gravity and shall meet the specified criteria. One set of test (3 tests in a set) shall be carried out for every change in source of material and shall meet the specified criteria.

(3) Measurement

Measurement of big boulder shall be in cubic meter. The volume of the boulder shall be measured in the truck / tractor carrying and dumping them near to the working site as directed. The volume for the payment shall be assessed after deducting 20 % voids from the volume measured in the truck.

(4) Payment

Big boulder in launching apron and slope pitching shall be paid for assessed volume (Volume measured in truck less void considered) at the respective contract unit rate which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1511 CONCRETE BLOCK WORKS IN LAUNCHING APRON AND SLOPE PROTECTION

(1) Concrete Block for Launching Apron

(a) Materials

Concrete blocks used for Launching Apron for protection of Riverbanks against scour shall be of required size (0.5mx 0.5m x 0.5m) and weight as specified in the contract or on drawing and shall be made of M15 concrete cast Insitu. The quality of concrete ingredients such as cement, sand, coarse aggregates, water, etc shall be as defined in section 800. The concrete block shall be hard, smooth and free from honeycomb, cracks or other defects. The density of concrete block shall not be less than 2,400 kg/m3. The minimum cement content of concrete shall be 250 kg/m3.

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(b) Construction

The casting of concrete blocks for launching apron shall be done as indicated on the drawings. The thickness of concrete blocks shall be 50 cm or as shown on the Drawing and approved by the Engineer. The thickness of concrete blocks maybe more than 50cm reinforced with steel as approved by the engineer in case of large rivers having high flow velocity with heavy debris (big boulders, trees, etc.) flow. The casting of concrete blocks shall be done manually or using machine as specified in the contract. Before laying the concrete blocks, the bed surface shall be made to the required profiles. Depressions shall be made even and thoroughly compacted to the extent possible. Hydraulic excavator shall be used for excavation/trimming of riverbed for preparation of construction site for casting concrete in case of large rivers. Concrete blocks shall be placed to the required length, thickness and depth as per the Drawing. The top surface of the launching apron shall be smooth as far as possible.

(c) Tests and Standard of Acceptance

Cement, Sand, Coarse aggregates, water, etc. used for casting concrete blocks shall be tested for their required qualities as per section 800; and quality results shall meet the specified criteria. One set of cube test (3 tests in a set) shall be carried out for every change in source of material and shall meet the specified criteria.

(2) Concrete block pitching for Slope Protection

(a) Materials

Concrete blocks used for slope pitching of Riverbanks against erosion shall be of required size (0.3mx 0.3m x 0.3m) and weight as specified in the contract or on drawing and shall be made of M15 concrete cast Insitu. The quality of concrete ingredients such as cement, sand, coarse aggregates, water, etc shall be as defined in section 800. The concrete block shall be hard, smooth and free from honeycomb, cracks or other defects. The density of concrete block shall not be less than 2,400 kg/m3.

(b) Construction

The casting of concrete blocks for slope pitching shall be done as indicated on the drawings. The thickness of concrete blocks shall be 30 cm as shown on the Drawing and approved by the Engineer. The casting of concrete blocks shall be done manually as specified in the contract. Before laying the concrete blocks, the surface shall be made level and smooth to the required profiles. Depressions shall be made even and thoroughly compacted. Concrete blocks shall be placed to the required length, thickness and depth as per the Drawing. The top surface of pitching shall be smooth as far as possible.

(c) Tests and Standard of Acceptance

Cement, Sand, Coarse aggregates, water, etc. used for casting concrete blocks shall be tested for their required qualities as per section 800; and quality results shall meet the specified criteria. One set of cube test (3 tests in a set) shall be carried out for every change in source of material and shall meet the specified criteria.

(3) Measurement

Measurement for cement concrete blocks in launching apron and slope pitching shall be in cubic meter as specified in the contract.

(4) Payment

Cement concrete blocks in launching apron and slope pitching shall be paid at the respective contract unit rate which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1512 DOLOS / TETRAHEDAL FOR RIVERBANK PROTECTION

(1) Material

Dolos/Tetrahedral may be used for riverbank protection against scour and erosion in large rivers like Koshi, Narayani, Karnali, Mahakali, etc. having high velocity and wave action causing danger to riverbanks. The materials used for construction of dolos/tetrahedral shall be precast concrete of grade M20 or more as specified in the contract or on the drawing and approved by the engineer. The materials (Cement, sand, Coarse Aggregates, Admixtures, Water, Steel, etc.) used for construction of dolos/tetrahedral made of concrete reinforced with steel shall be of required quality conforming to the requirement specified in section 800. Steel form work to be used for casting dolos/tetrahedral shall be of special quality and type depending upon the designed shape of the structure as approved by the Engineer. Unless specified otherwise, the weight of each dolos shall not be less than 6.5 tonne. The weight of each tetrahedral shall be between 0.46 tonne to 5.7 tonne, unless otherwise specified in the contract or drawing. Depending upon the degree of severity of the working site, the size and weight of dolos / tetrahedral maybe varied as approved by the Engineer.

(2) Construction

The dolos/tetrahedral precasted for use shall be transported to the working site by using heavy equipment as required. The dolos/tetrahedral shall be gradually laid on the required riverbank site using heavy crane. Due care shall be taken while placing by crane to ensure maximum interlocking among the members. Laying shall be done for a small length first and shall be tested to conform proper interlocking. If the required interlocking will be achieved, further laying shall be continued upto full length desired. Since the dolos/tetrahedral are heavy elements and their laying by the machine shall be done under water, every care shall be taken to ensure the safety working environment.

(3) Tests and Standard of Acceptance

Cement, Sand, Coarse aggregates, Admixtures, Steel Reinforcement, Water, etc. used for precasting dolos/tetrahedral shall be tested for their required qualities as per section 800; and quality results shall meet the specified criteria. One set of cube test (5 tests in a set- after 3 days, 7days, 14 days, 21 days and 28 days) shall be carried out for every change in source of material and shall meet the specified criteria (compressive strength).

(4) Measurement

Measurement for precast dolos/tetrahedral used for riverbank protection shall be in cubic meter as specified in the contract. Unless otherwise specified, Special formwork and steel reinforcement be measured separately.

(5) Payment

Precast dolos/tetrahedral used for riverbank protection shall be paid at the respective contract unit rate which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115. Unless otherwise specified, Special formwork and steel reinforcement shall be paid at respective contract unit rate separately.

1513 RCC PILE FOR RIVERBANK PROTECTION WORKS

(1) Cast-In-Situ Piles

Cast in situ concrete piles may be either installed by marking a bore into the ground by removal of material or by driving a metal casing with a shoe at the tip and displacing the material laterally. The two types of piles are termed as bored and cast-in-situ piles and driven shell and cast-in-situ piles respectively.

(a) Bored and cast in-situ piles

(i) Steel Casing

When permanent steel casing is shown on the Drawing, the minimum thickness shall be 10 mm. The minimum length shall be from 100 mm above the bottom of the pile cap to 5 meter under the riverbed or into the firm strata with joints between casings as approved by the Engineer.

(ii) Concrete

The concrete shall conform to the requirements specified in Section 800. The density and consistency of the concrete shall conform to the termite casting method. Sufficient workability (slump) of all the concrete during the casting and handling of casing including reasonably calculated delays, shall be secured. All relevant concrete properties such as slump, time of setting, temperature and strength shall be measured during concrete tests performed.

(iii) Reinforcement

The reinforcement shall conform to Section 800.

(iv) Drilling Fluid

The following requirements shall be complied with, if bentonite mud is used to stabilize the boreholes:

Supply

A certificate shall be obtained by the Contractor showing the properties of the consignment delivered to the site. This certificate shall be made available to the Engineer for his approval. The Contractor shall get approval of the Engineer for any other material proposed by him for the drilling fluid.

Mixing

Bentonite and any other material shall be mixed thoroughly with clean water to make a suspension which shall maintain the stability of the pile excavation for the period necessary to place concrete and complete the construction.

Tests

The frequency of testing drilling fluid along with method and procedure of sampling shall be proposed by the Contractor for approval by the Engineer prior to the commencement of the work. The frequency may subsequently be varied as required, depending on the consistency of the result obtained. The Contractor shall supply all equipment and experienced operators required to carry out tests on the drilling mud. No additional payment shall be made for these tests which shall be considered as an essential part of the drilling operations.

(v) Construction Methods

The Contractors shall demonstrate to the satisfaction of the Engineer that his proposed construction method for the pile do not weaken the pile shaft by contamination of the concrete by sectional reduction, by washing out of cement, by breaking during pulling of temporary casing or in any other way including the construction of neighboring piles. The Contractor shall describe the construction method he proposes, including information on boring equipment, materials, method of boring and quality control.

The construction procedure shall be as follows:

(i) If permanent steel casings is not specified, a sufficient length of temporary steel casing shall be used to stabilize the upper part of the borehole.

(ii) Boring and excavation inside the steel casing shall be carried down to the casing toe level or to a level approved by the Engineer. The excavation shall be continued to final pile tip level using either temporary casing under water or using drilling mud. The fluid level inside casing shall at all times be at least 2 meters higher than outside the casings.

(iii) All mud or sedimentation from the bottom of borehole shall be cleaned up.

(iv) Reinforcement cage, inspection pipes etc. shall be placed shown on the drawing or instructed by the Engineer.

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(v) Concreting underwater or drilling fluid shall be carried out continuously using termite method.

(vi) Withdrawing of the temporary boring casing to the instructed level shall be carried out concurrently with concreting.

(vii) After hardening, the top section of the concrete pile shall be broken to reach sound concrete in the pile, if pile cap is required for riverbank/toe protection.

The Centre of the complete pile at cut off level shall not deviate more than 100 mm from the theoretically correct position shown on the drawing. The inclination of the pile shall not deviate more than 1:100 from vertical. The Contractor shall provide suitable equipment such as inverted pendulum, to check the vertically of the boreholes at intervals during drilling and prior to concreting.

(vi) Boring

Methods of excavation shall be proposed by the Contractor for approval of the Engineer. Piles shall not be bored so close to other piles which are cast and contain workable or unset concrete likely to flow. Boring and excavation for a pile shall not commence until 24 hours after completion of any pile within a radius of 6 meters centre to centre. Temporary casing of approved quality or an approved alternative method shall be used to maintain stability of pile excavation which might otherwise collapse.

Pile through water and/or soft upper soil layers shall be provided with permanent steel casing if shown in the Drawing. The pile boring shall be carried out using temporary steel casing bored in pile toe, to the level of side fall or to a level approved by the Engineer. Before concreting the temporary casing shall be gradually withdrawn. Under certain circumstances the Contractor may permitted to bore all part or the pile without casing under water or using drilling fluid to stabilize the borehole.

Where borehole is formed without casing under water or using drilling fluid for maintaining the stability of a boring, the level of the water or fluid in the excavation shall be maintained so that the water or fluid pressure always exceeds the pressure exerted by the soils and external ground water. The water or fluid level shall be maintained at a level not less than 2 meters above the level of the river water level or any artesian pressure level.

In the event of a rapid loss of water or bentonite suspension from the pile excavation, the excavation shall be backfilled without delay and the instruction of the Engineer shall be obtained before excavation at that location is resumed

(vii) Pumping

Pumping from the borehole shall not be permitted unless a casing has been placed into a stable stratum which prevents the flow of water from other strata in significant quantities into the boring, or unless it can be shown that pumping shall not have a detrimental effect on the surrounding soil or property.

(viii) Removal of Obstruction

Where boulder or other obstruction renders it impossible to bore the pile, excavation operation inside pile casing as directed by Engineer shall be carried out to remove obstructions. The Contractor shall be reimbursed from such operation only when the largest dimension of the obstruction exceeds 200 mm and the obstruction is found more than 2 meters below riverbed.

Disturbed and/or undisturbed samples of the soils from boreholes shall be submitted to the Engineer. The contractor shall allow for carrying out sampling and tests to check soil strength including field tests like SPT tests as required by the Engineer.

(ix) Final Toe Level of Piles

The final toe level shall be as indicated on the drawing or as instructed by Engineer after due consideration of the Contractor's proposals, boring logs and test results.

The final toe level of other piles may subsequently be altered according to the results of the tests loading detail in the section.

(x) Inspection and cleaning bottom of Excavation

The time between final excavation including bottom cleaning and the start of concreting shall be reduced as much as possible and in any case shall not exceed 6 hours.

The cleaning shall be done by an approved method. Before cleaning bottom of every excavation, notice shall be given to the Engineer. The Contractor shall show, to the satisfaction of the Engineer, that the bottom of the excavation is clean.

If boring without casing, the diameter of the borehole for a representative number of piles shall be measured by calliper to the placing of concrete.

These measurements shall be done by the Contractor using approved equipment and no reimbursement shall be made for this.

(xi) Placing Reinforcement

The reinforcement shall be placed as indicated on the Drawing. Reinforcement in the form of a cage shall be assembled with additional support, such as spreaders forks and lacings necessary to form a rigid cage. Hoops, links or helical reinforcement shall fit closely around the main longitudinal bars and be bound to them by approved wire, the ends of which shall be turned into the interior of the pile or pour. Reinforcement shall be placed and maintained in position. The cover to all reinforcement shall be not less than 75 mm.

Joints in longitudinal bars in piles with tension (for instance for test loading) shall be carried out by welding unless another method has been approved by the Engineer.

(xii) Placing Concrete

Approval from the Engineer

No concreting shall take place before the bottom of excavation has been cleaned. The Contractor shall get borehole inspected and obtain approval in writing from the Engineer.

General Requirements

While placing concrete, these requirements shall be complied with

i. The method of placing and workability of the concrete shall be such that a continuous monolithic concrete shaft of the full cross section is formed.

ii. The concrete shall be placed continuously and without such interruption as would allow the previously placed batch to have hardened. In this respect the Contractor shall submit details of his contingency plans, standby plants etc. to be utilized in the event of an equipment failure.

iii. The use of pumped concrete and the methods in its use shall be approved.

iv. The Contractor shall take precautions in the design of the mix and placing of the concrete to avoid arching of the concrete in a casing. No spoil, liquid or other foreign matter shall be allowed to contaminate the concrete.

v. Concrete to be placed under water or chilly fluid shall be placed by termite and shall not be discharged freely into the water or drilling fluid.

vi. Before concrete, measures shall be taken to ensure that there is no accumulation of silt or other material at the base of the boring. The Contractor shall ensure that heavily contaminated bentonite suspension, which could impair the free flow of concrete from the pipe of the termite, has not accumulated in the bottom of the hole.

vii. A sample of the bentonite suspension shall be taken from the base of the boring using an approved sampling device. If the specific gravity of the suspension exceeds 1.25, the placing of concrete shall not proceed. In this event the Contractor shall modify the mud quality. The concrete shall be a rich and coherent mix of high workability in accordance with the requirement of Section 800.

viii. The concrete shall be placed in such a manner that segregation does not occur.

ix. During and after concreting damage to the concrete from pumping and dewatering operations shall be avoided.

x. The hopper and pipe of the termite shall be clean and watering throughout. The pipe shall extend to the base of the boring. A sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the pipe of the termite and the water of drilling fluid. At all times the pipe shall penetrate the concrete placed and shall not be withdrawn from the concrete until completion of concreting. The bottom of the termite pipe shall be kept at least 1.5 meters under the surface of concrete. At all times a sufficient quantity of concrete shall be maintained within the pipe to ensure that the pressure from it exceeds that from the water or drilling fluid. The internal diameter of the pipe termite shall not be less than 150 mm for concrete made with 20 mm aggregate and not less than 200 mm for concrete made with 40 mm aggregate. It shall be so designed that external projections are minimized, allowing the termite to pass through reinforcing cages without causing damage. The internal face to the pipe of the termite shall be free from projections.

xi. The Contractor shall maintain a continuous record of the volume of concrete used and the level of the concrete in the pipe. Any deviations from the theoretical, or expected, volume/level relationship shall be immediately reported to the Engineer.

Workability of Concrete

Slump measured at the time of discharge into the pile shall be in accordance with that given in the Table 15.19.

Table 15.19: Slump of Concrete for Pile Boring

Pilling mix Workability	Slump		Typical conditions of use
	Minimum mm	Range mm	
A	75	75-150	Placed into water free unlined or permanently lined bore of 600 mm diameter or over where casting level lies below temporary casting: reinforcement widely spaced bearing ample room for free movement of concrete between bars
B	100	100-200	Where reinforcement is not spaced widely where cut off level of concrete is within temporary casing where pile bore is water free and the diameter is less than 600 mm.
C	150	150	Where concrete is to be placed by termite under water or chilly Mud or by pumping.

(xiii) Extraction of Temporary Casing

A. Workability of Concrete

The temporary casing shall be withdrawn while the concrete remains sufficiently workable to ensure that it is not displaced or lifted during extraction.

B. Concrete Level

When the casing is being extracted a sufficient quantity of concrete shall be maintained in it to ensure that pressure from external water, drilling fluid or soil is exceeded and that the pile is neither reduced in section nor contaminated. The toe of the temporary casing shall be kept at a minimum of 2 meters under the outlet of the termite.

Adequate precautions shall be taken in all cases where excess head of water or drilling fluid exists.

The pile shall be concreted with certain over height to allow for chiseling off the top concrete down to sound hard concrete.

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C. Vibrating Extractors

The use of vibrating casing extractors shall be permitted for the extraction of the casing.

D. Reinforcement Cage

During concreting and puling casing, the reinforcement cage shall be secured against uplift the top shall be kept under close monitoring.

E. Supervision

The execution of the pile concreting shall be supervised by a qualified and experienced person of the Contractor, who shall keep records on the relation between quantity of concrete used, level of concrete and withdrawal of casing.

(2) Precast Rcc Pile

Specification for pre-cast concrete piles shall conform to those contained in Clause 8 of IS: 2911 (part 1 Section 3), if not covered by Section 800. Every pile shall be marked with the date of casting and an identification number. Pre-cast concrete piles to be used for riverbank protection shall be of the size (normally 300mm or 500mm dia) and shape (normally circular) as shown on the designed drawing. The length of pile shall be as per the design performed based on site requirement and not normally it should not exceed 25 meters. Piles shall be cast with a driving point for hard driving and shall be cast with a metal shoe approved by the Engineer.

(a) Driving Equipment

(i) Pile Driving Frames on leads

Leads shall be required for all types of hammers. Leads shall be so constructed as to allow free movement of the hammer and shall be rigid enough to hold the pile in correct alignment during the driving operation. The leads should be of such length, where practicable, that the use of followers shall not be necessary. The use of hanging leads, guyed leads or other leads shall be subject to the approval of the Engineer, whose approval, if given, shall not relieve the Contractor of the responsibility of driving the piles to the place and vertically tolerances allowed in the contract.

(ii) Pilling Hammers

Pile Hammers, other than drop hammers, shall be of approved steam, air or diesel Hammers that develop sufficient energy per blow to drive the piles at a penetration rate of not less than 5 mm per blow at the required bearing value. Steam or air hammers shall be with boiler or air capacity at least equal to that specified by the manufacturers of the hammers to be used. The boiler or compressor shall be equipped with an accurate pressure gauge. The value, mechanism and other parts of the hammers shall be maintained in good condition and working order so that the length of stroke and number of blows per minute for which the hammer is designed shall be obtained. Inefficient steam, air, or diesel hammers shall not be used and hence such hammers shall be removed from the site. As a general guide the size of the hammer normally required for steel piles shall be one which develops approximately 1100 kg meter energy per blow. Pre-cast concrete piles and steel shell for cast-in-situ piles longer than 15 meters shall normally require a hammer which develops 1725 kg meters energy per blow. Drop hammers shall in no case weigh less than the combined weight of the pile, dolly and helmet. The Contractor shall, furnish the Engineer with evidence of the weight of the drop hammer as he requires.

(iii) Pile Driving Helmets and Dolly's

A driving helmet shall be used which fits closely over the head of the pile. A cushion block of coir or wood shall be used between the pile head and the helmet, and the helmet shall have a dolly of suitable material on the upper side.

(b) Pile Driving

(i) General

The Contractor shall notify the Engineer at least 24 hours before beginning any pile driving operations and no piles shall be driven unless the Engineer or Engineer's representative or his Inspector is present. Before any foundation piles are driven in any unit including test piles, the excavation shall be made, approximately, to the planned footing level. Piles to be driven through embankments over 1.5 m in depth constructed by the Contractor shall be driven in holes excavated through the embankment of dimensions not less than the pile dimensions plus 15 mm. After driving, the space around the pile shall be filled with dry sand or single size gravel. During pile driving operations the water level in the excavation shall be kept below the top of the pile. Under water pile driving shall only be permitted when the contract calls for a concrete seal foundation. In such cases, the piles shall be driven by a mechanical hammer equipped to drive when submerged. When the top of the hammer is submerged during driving, it shall be equipped with accurate measuring detachable measuring rods, for the purpose of recording pile penetration. Care shall be taken to obtain accurate location and spacing of the pilling. In all cases of underwater driving, the equipment and method to be used shall be approved by the Engineer in writing. When satisfactory penetration of piles cannot be obtained without damage to the pile from driving, and the character of the soil is considered suitable, the Contractor may, with the Engineer's approval, use water jets in sufficient numbers to obtain the desired penetration. Before the desired penetration is reached the jets shall be withdrawn and the pile shall be allowed the jetting or the provision of jetting equipment. Water jets shall not be used as an aid for driving steel piling. The driving of piles by means of followers shall be avoided if practicable and shall only be done with the written permission of the Engineer, who may require that one pile from any group of 10 or less shall be a long pile driven without a follower to determine the average bearing power of the group. Sawing or cutting the body of a pile to assist in springing it to proper location shall not be permitted. If a pile vibrates excessively or shows signs of buckling during it shall be braced or guyed as directed by the Engineer. Broken, spilt or wrongly treated piles shall not be measured for payment and if required by the Engineer they shall be completely withdrawn and replaced by satisfactory piles.

(ii) Installation

Installation of piles shall be carried out in accordance with the pile layout Drawing or as directed by the Engineer.

The Engineer shall decide the sequence of the group of piles that the Contractor should undertake for installation and shall follow this sequence. In a group the installation shall proceed from those on the centre of the group towards those on the periphery.

(iii) Temporary Arrangement

The Contractor shall ensure that free standing piles are temporarily braced on stayed immediately after driving to prevent loosening of the piles in the ground and to ensure that no damage resulting from oscillation, vibration or movement of any free-standing pile length can occur.

(iv) Tolerance in Driving

During driving, the piles shall not deviate from the vertical or the specified rake (in the case of racer piles) by more than 40 mm per meter of pile length, and after driving the centre of the pile at cut-off level, shall be not more than 150 mm from its planned location.

(v) Cutting of Pre-Cast Concrete Piles

Concrete piles shall be cut off at such level that they shall extend into the cap or footing if required for riverbank protection as indicated in the Drawing.

(3) Measurement

For supply of precast concrete piles of specified cross-section, the measurement shall be in metres of the length of piles ordered in writing by the Engineer measured from the head to the butt of the shoe. Reinforcement in precast concrete piles shall not be measured separately for payment as it is deemed to be included in the cost of pile.

For cast-in-situ driven and bored concrete piles of specified cross-section, the measurement shall be the length in metres of the accepted pile that remains in the finished structure complete in place. Reinforcement

in cast-in-situ driven and bored concrete piles shall be measured in kg separately for payment.

For installation of the pile, i.e. by driving in the case of precast concrete and cast-in-situ driven piles, and by boring in the case of cast-in-situ bored piles the measurement shall be the length in metres that remains in the finished structure complete in place.

For steel liners/casing shown on the drawings to be permanently left in place, the measurement shall be by weight in tones that remains in the finished structure complete in place, limited to that shown on drawings or ordered by the Engineer.

For the pile cap, the quantity of concrete shall be measured in cubic metres, while reinforcement in pile cap shall be measured in tones/kg as specified.

(4) Payment

The contract unit rate shall be the full and the final compensation to the Contractor for Installation of precast concrete piles. The cost of reinforcement in precast concrete piles shall be deemed to be included in the quoted rate for piles.

The contract unit rate shall be the full and the final compensation to the Contractor for all expenditures incurred by the Contractor for incidentals and for doing all the works involved in driving, placing filling materials for cast- in-situ or driven piles, cutting off piles as specified in this specification in addition to those specified in Clause 115.

Reinforcement in cast-in-situ driven and bored piles shall be paid at the contract unit rate as specified in Section 800.

Permanent steel liners shall be paid at the contract unit rate. The contract unit rate shall be the full and the final compensation to the Contractor for, fabrication and placing the steel liner to the required depth as shown on the drawings and as ordered by the Engineer in addition to those specified in Clause 115.

Concrete and reinforcement in pile cap shall be paid separately at the contract unit rate as specified in the contract.

1514 BAMBOO PILE

Bamboo piles of required size and length shall be made and driven at the required location for protection of riverbanks from erosion. Bamboo piling is a low cost but effective technology to be used for river training works. Bamboo being easily available in Terai region of Nepal, it is frequently used for river training of rivers flowing through plain Terai areas. Because of low cost and easy access, bamboo piling is effectively used during flood fighting in Terai Rivers.

(1) Materials

Bamboo piles of required diameter and length shall be prepared from the selected straight, sound and strong bamboo having required strength and moisture content. The moisture content shall not be more than 12%. Borer attack and decay in the culms shall not be permitted. Splits/cracks and blue stains are also not permissible as these defects affect strength properties.

(2) Bamboo Pile Driving

Before actual pile driving, piles of required size and length shall be prepared from the selected bamboos. Pointing edge of each bamboo pile shall be prepared in order to make the driving easy and comfortable. Pile lines shall be marked on the site and pile driving shall be processed at the designed interval with the help of wooden hammer or Monkey hammer or Water jet as prescribed in the contract. Iron cap shall be used while driving piles using wooden hammer or monkey hammer in order to protect the pile head from being teared. If the ground formation is hard, and hammering method is not feasible to drive the length up to the designed depth Water jetting method shall be used. In all cases, the depth of pile below ground level and that above ground level shall be maintained in order to protect the riverbanks as designed.

(3) Bamboo Fabric/ chachari

Bamboo fabric or bamboo chachari required to be used with bamboo piling shall be prepared of required size and dimension as per design from the bamboos approved by the Engineer. Bamboo chachari shall be installed along with bamboo piles using Nails and SWG GI wire as required.

(4) Measurement

Making of bamboo piles shall be measured in meter or number as specified in the contract or on the drawing. Driving of bamboo piles including supply of material and making shall be measured in meter or number as specified in the contract or on the drawing. Bamboo fabric/chachari shall be measured in Sqm.

(5) Payment

Payment of making bamboo piles, driving of bamboo piles including supply of material and making, bamboo fabric/chachari shall be made as per unit rate specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1515 PORCUPINE

(1) General

Porcupines are a form of permeable structure designed to reduce flow velocity and trap sediment. They have pole-like projections in all directions, resembling a porcupine with its quills sticking into the air. Porcupines can be used in a line forming a spur into a river, as silting aprons for larger spurs, and in a longitudinal line along an embankment.

They are used as flood control structures and for riverbank and bed protection as these function as bank protection, screens, spurs, or dampeners. The structures are flexible, which ensures stability against extreme water forces and even earthquakes. Porcupines reduce the flow velocity, intercept and break eddies formed by floodwater, and fill up scour holes with silt. Porcupines increase the roughness of the channel thereby deflecting the eroding current away from the bank.

Originally porcupines were made of timber or bamboo, but these have a limited life span. The use of wooden and bamboo is replacing the RCC porcupine. Porcupines can be constructed in two shapes, tetrahedral and prismatic.

(2) Scope

This section comprises construction of concrete porcupines of different sizes and different grades of concrete. Bamboo Porcupine driven up to the scour level and Bamboo porcupines anchored with gabion works for the protection of bank against erosion and scour. Porcupines can be constructed as screens, spurs, or dampeners.

(3) Construction of Porcupines

Porcupines used as spurs (bars across) shall be aligned at 2–5° upstream of the flow. Spurs shall be single, double, or triple rows as mentioned in the drawing based on the velocity of flow, the width of the bank line channel, and the spacing between spurs. The porcupines during construction of spur shall be placed so that they touch each other at the base, and with the lines staggered if there are multiple rows. The spur shall extend from the highest flood level line to the deepest scour point of the bank line channel plus a marginal distance as a factor of safety. The spurs shall be extended to link up with the continuous non-submerged riverbank or road – above the highest flood level – to avoid out flanking. The spacing between the rows of spurs shall be close to avoid formation of lagoons in between. When the curvature of the eroding bank is sharp and the flow velocity is high, porcupine spurs shall be placed less than 10 m apart.

Porcupine dampeners shall be laid in a row along the riverbank functioning similar to revetment at spacing as specified in the drawing (generally 3m c/c in in case of 3m long concrete members of porcupine and 2m c/c in case of 2m long concrete members of porcupine). Rows of porcupine dampeners which depend upon

the depth of flow shall be as specified in the drawings (generally 2 rows on either side of toe for flow depth less than 3m and more rows at specified spacing upto flood level for depth of flow more than 3m).

Porcupine Screen which is constructed for the closure of the secondary channel shall be constructed in 5 to 9 rows or as specified in the drawing at the spacing of 2 or 3 m c/c depending upon the length of the members of the porcupines. Porcupine screens shall be constructed to cover a part or whole width of the secondary channel as specified in the drawing. If screen is constructed to cover whole width of the secondary channel, it shall be extended one third of the width of the channel on either side of the channel.

(a) Concrete Porcupine

Concrete porcupine shall be constructed in tetrahedral shape consisting of 6 members of specified length and size (generally 3m*0.1m*0.1m or 2m*0.1m*0.1m) made of Reinforced concrete of specified grade. The quality of concrete ingredients and strength of concrete shall be as specified in section 800. Though quality control of RCC struts is difficult because each strut cannot be tested separately, a rebound hammer shall be used to test the uniformity of strength of struts (member of concrete porcupine) throughout.

(b) Bamboo Porcupine

Bamboo porcupine used for this purpose shall be made of bamboo free from defects and test complying to IS 6874:2008. Bamboo porcupines shall be made of 3 to 6 m long bamboo of 75 mm diameter or as specified in the drawing. Generally, locally available bamboos of girth 20 cm to 30 cm shall be used for the porcupines. The larger girth of 25 cm to 30 cm shall be used for the main members, whereas, the smaller girth of 20 cm to 25 cm shall be used for bracings. If suitable sizes are not available, use of bamboos of girth smaller than the specified shall be used if permitted by the Engineer, provided it may not significantly affect the overall result. Main vertical members of bamboo porcupines shall be driven possibly up to scour depth by hammering or by water jetting as specified in the contract.

Though bamboo porcupines are not so durable as RCC porcupine, they being low cost alternatives to erosion/bank protection, are frequently used for temporary bank protection during emergency due to floods owing to easy availability, ease of construction, fast workability and low construction cost.

(c) Bamboo Porcupine anchored with gabion

Bamboo porcupines in bamboo porcupines anchored with gabions shall be same as specified in section 1514(b) above. However, main vertical members shall not be driven. Assembled porcupines shall be laid in position at site being anchored with toe gabions to prevent from displacement during flood. Porcupines shall be tied with the toe gabions using SWG wire, D-bolt and Cable rope of required quality and dimensions. Quality of Gabion works i.e. GI box and boulder shall be as specified in relative section of this specification.

(4) Measurement and Payment

Concrete porcupine, Bamboo porcupine and bamboo porcupine anchored with gabions shall be measured in set or number as specified in the contract or on the drawing.

Payment of Concrete porcupine, Bamboo porcupine and bamboo porcupine anchored with gabions shall be made as per unit rate specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1516 GEOBAG

(1) Scope

This section consist of providing, filling and laying geobags of required size as specified in the contract or on the drawing for bank revetment and spur construction in order to protect banks from erosion and scour.

(2) Construction

Geobag bank revetment or spur shall be constructed as per the design drawing. Geobags filled with

approved quality of sand and stitched properly shall be laid on single or multiple layers based on the velocity of flow as specified. Generally, geobags encaged in nylon/ polypropylene rope net shall be of single layer and thickness of geobag revetment shall be more than the thickness of boulder revetment. Filter material for geobags revetment is not necessary. However, filter materials if specified to be used shall be considered where safety for removal of material in between the bags shall have to be ensured.

(3) Quality of Materials

Sand to be used for filling geobag shall be free from silt and clay. It shall be of desired quality as specified in relevant section of this specification. Specification of Non-woven geobag of size (1m*0.7m) shall be:

Material and make: Non-woven Geo Bag should be made of virgin material and should not be made of recycle material. Needle punched, staple fiber, high elongation, non-woven PET Geo Textile should resist Ultraviolet, rooting and biological degradation, naturally encountered acid and alkalis.

Mass (GSM): As per ASTM: D 5261 = 300 gm/m^2

Wide width Tensile Strength (Both Direction)	: As per ASTM: D4595 = 9.00 KN/M
Elongation (Both direction)	: As per ASTM D 4595 = 50%
Static Puncture Strength	: As per ASTM D 6241 = 1400N
AOS (Apparent Opening Size)	: As per ASTM D 4751 =100 micron
Permittivity	: As per ASTM D 4491 = 1.25
UV Resistance @500 hrs.	: As per ASTM D 4355 (TYP) =70%
Trapezoidal Tear Strength	: As per ASTM D 4533 = 340N

Volume of filled bag = 0.07 m^3

Weight of filled bag = 126 Kg

Stitching: Ring Spun Yarn stitches with 2500-3500 denier (PET/PP): Double line chain stitch with overlap with stiches along the edges @ minimum 15 stitches/100mm

(4) Measurement and Payment

Geobags laying and filling works shall be measured in number of bags.

Payment of Geobags laying and filling works shall be made as per unit rate specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1517 SANDBAG/CEMENT BAG

(1) Scope

This section comprises filling of sandbags and laying in position for bank protection against erosion and scour during flood fighting. Sand/Cement bags are simple, local, low-cost materials which have appreciable and effective use during time of emergency floods as revetment, filling materials for fencing and embankment raising. As sandbags have short lives, these should not be used for long term flood protection measures.

(2) Construction

Size of the sandbags shall be 75 cm (30 inch) high, 50 cm (20 inch) wide and 10 cm (4 inch) thick and contain about 1.25 cubic feet of sand. Sandbags bank revetment shall be constructed as per the design drawing. Sandbags filled with approved quality of sand and stitched properly shall be laid on single or multiple layers based on the velocity of flow as specified. Generally, Sandbags encaged in nylon/ polypropylene rope net shall be of single layer and thickness of geobag revetment shall be more than the thickness of boulder revetment. The bags should be about one-half full and tied near the top so that the sand can move easily. Overfilled bags and bags tied too low lead to gaps in the bund or wall, which allows

water to seep through. Filter material for Sandbags revetment is not necessary. However, filter materials if specified to be used shall be considered where safety for removal of material in between the bags shall have to be ensured.

Filling sandbags usually shall be a two-person operation. One member of the team shall hold the bag on the ground slightly in front of his or her spread feet and the second shall shovel the sand into the bag. The first layer of bags shall be placed lengthwise on the bund (parallel to the flow), lapping the bags so that the filled portion of one bag lies on the unfilled portion of the next, with the untied open end of the bag facing downstream. Adjacent rows or layers shall be offset by one half bag length to eliminate continuous joints.

(3) Quality of Materials

Sand to be used for filling sandbag shall be free from silt and clay. It shall be of desired quality as specified in relevant section of this specification. Sandbags should be new and free from any sort of wear and tear.

(4) Measurement and Payment

Sandbags laying and filling works shall be measured in number of bags.

Payment of Sandbags laying and filling works shall be made as per unit rate specified in the contract, which shall be full and final compensation for the cost of compliance of all requirements specified in Clause 115.

1518 NYLON ROPECRATE

(1) Scope

This section comprises supplying and delivery of Nylon Rope crates of specified size with specified mesh made from specified nylon ropes. Nylon Rope crates shall be used for emergency flood fighting. Nylon boxes filled with sandbags, shall be launched into flowing water next to the bank being eroded during floods. This will help to prevent toe erosion by lowering flow velocity and inducing siltation. This eventually deflects the flow away from the bank and protects the bank from being eroded.

(2) Construction

Constructed nylon crates of specified dimension shall be supplied for use during flood fighting in large rivers especially in plain (Terai) area. Size of the nylon crates shall be 6m*3m*0.75m having rectangular mesh 20cm*20cm made from 8mm dia. nylon rope or 3m*1.05m*1.05m having rectangular mesh 15cm*15cm made from 4mm dia. nylon rope as specified in the BOQ or on the drawing.

(3) Quality of Materials

Nylon crates shall be new, made from original material and shall not be woven using recycled materials.

(4) Measurement and Payment

Supply and Delivery of Nylon crate of required dimensions shall be measured in number of boxes.

Payment of Supply and Delivery of Nylon crate shall be made as per unit rate specified in the contract, which shall be full and final compensation for the cost of compliance of all requirements specified in Clause 115.

1519 ARTICULATING BLOCK (AB) FABRIC FORMED CONCRETE LINING

(1) General

Articulating Block Mats form cable-reinforced concrete block mattresses that resist erosive forces. They are often constructed where a revetment is exposed to frontal attack by wave action.

AB Mats are typically used to protect coastlines, canals, rivers, lakes, reservoirs, underwater pipelines, bridge piers, and other marine structures from propeller wash, ship wakes, wind waves, currents, and high velocity flows. They are also used in environmental construction for landfill caps, down chutes, and collector channels.

Government of Nepal
Ministry of Energy, Water Resources and Irrigation
Department of Water Resources and Irrigation
Jawalakhel, Lalitpur

(2) Material

Articulating Block Mattress consists of a series of compartments linked by an interwoven perimeter. Grout ducts interconnect the compartments, and high strength revetment cables are installed between and through the compartments and grout ducts. Once filled, the AB Mats become a mattress of pillow-shaped, rectangular concrete blocks. The interwoven perimeters between the blocks serve as hinges to permit articulation. The cables remain embedded in the concrete blocks to link the blocks together and facilitate articulation. Some relief of hydrostatic pressure is accomplished through the filtration bands formed by the interwoven perimeters of the blocks.

The fabric forms shall be composed of synthetic yarns formed into a woven fabric. Polyester yarns shall be used in the manufacture of the fabric. The forms shall be woven with a minimum of 50% textured yarns (by weight). Partially oriented (POY), draw-textured, and/or staple yarns shall not be used in the manufacture of the fabric. Each layer of fabric shall conform to the physical, mechanical and hydraulic requirements Mean Average Roll Values listed in Table 15.21. The fabric forms shall be free of defects or flaws which significantly affect their physical, mechanical, or hydraulic properties. The material property requirements of Articulating Block Fabric are listed below;

Table 15.20 Typical Dimensions and Weight

Product and sizes	AB400	AB600	AB800	AB1000	AB1200
Average Thickness, in (mm)	4 (102)	6 (152)	8 (203)	10 (254)	12 (305)
Mass per unit area, lb/ft^2 (kg/m^2)	45 (220)	68 (330)	90 (440)	113 (550)	135 (661)
Mass per block, lb (kg)	88 (39.8)	188 (85.2)	325 (148)	563 (255)	844 (382)
Nominal Block Dimension, in (mm)	20 x 14 (508 x 356)	20 x 20 (508 x 508)	20 x 26 (508 x 660)	30 x 24 (762 x 610)	30 x 30 (762 x 762)
Concrete Coverage ft^2/yd^3 (m^2/m^3)	75 (9.1)	50 (6.1)	38 (4.6)	30 (3.6)	25 (3.0)
Shear Resistance, lb/ft^2 (kg/m^2)	8 (203)	10 (254)	12 (305)	14 (356)	16 (406)

Table 15.21 Property Requirements – Articulating Block Fabric

	Test Method	Units	MARV#
Physical Properties			
Composition of Yarns	Not Applicable		Polyester
Mass Per Unit Area (single-layer)	ASTM D 5261	g/m^2	>200
Mass Per Unit Area (double-layer)			>400
Thickness (single-layer)	ASTM D 5199	mm	0.35
Mill Width (Woven)	Not Applicable	m	3.00
Mechanical Properties			
Wide Width Tensile Strength – MD | TD	ASTM D 4595	kN/m	50 | 50
Wide Width Elongation at Break - MD | TD	ASTM D 4595	%	>10 | >10
Trapezoidal Tear Strength - MD | TD	ASTM D 4533	N	350 | 350
CBR Puncture Strength	ASTM D 6241	N	5100
Hydraulic Properties			
	Test Method	Units	MARV# Range
Apparent Opening Size (AOS)*	ASTM D 4751	mm	< 0.8
Water Flow Rate*	ASTM D 4491	l/m²/min	> 1000

** Handling may vary the above properties in its application.*

 # MARV stands for Minimum Average Roll Value and is calculated as the average minus two standard deviations. Statistically, it yields approximately 97.5% degree of confidence that any samples taken from quality assurance testing will meet or exceed the values described above.

Articulating Block mattress shall consist of double-layer woven fabric joined together by spaced, interwoven fabric into a matrix of rectangular compartments. Cords shall connect the two layers of fabric at the center

of each compartment. The cords shall be interwoven in two sets of four cords each, one set shall cross from the top layer to the bottom layer and the other from the bottom layer to the top layer. Each cord shall have a minimum breaking strength of 160 lbf when tested in accordance with ASTM D 2256.

Fabric form compartments shall each have six ducts, two on each of the long sides and one on each of the short sides to allow passage of the fine aggregate concrete between adjacent compartments. The fine aggregate concrete filled, cross-sectional area of each duct shall be no more than 10 percent of the maximum filled cross-sectional area of the block lateral to the duct.

Articulating Block consists of Cables present in Longitudinal or Both directions which is designed as per the site conditions. Cables shall be installed in the longitudinal direction between the two layers of fabric. Two longitudinal cables shall pass through each compartment in a manner which provides for the longitudinal and lateral binding of the finished articulating block mat. The cables shall enter and exit the compartments through opposing ducts. All longitudinal cables within each filled concrete block shall be completely embedded in the fine aggregate concrete.

Mill widths of fabric shall be a minimum of 3.0 m. Each selvage edge of the top and bottom layers of fabric shall be reinforced for a width of not less than 34 mm by adding a minimum of 6 warp yarns to each selvage construction. Mill width rolls shall be cut to the length required, and the double-layer fabric separately joined, bottom layer to bottom layer and top layer to top layer, by means of sewing thread, to form multiple mill width panels with sewn seams on not less than 2.9 m centers.

Fabric form panels shall be factory-sewn, by jointing together the layers of fabric, top layer to top layer and bottom layer to bottom layer, into predetermined custom sized panels. Sewn seams shall be downward facing as shown on the Contract Drawings. All sewn seams and zipper attachments shall be made using a double line of U.S. Federal Standard Type 401 stitch. All seams sewn shall be not less than 17 kN/m when tested in accordance with ASTM D 4884. Both lines of stitches shall be sewn simultaneously and be parallel to each other, spaced between 6.3 mm to 19 mm apart. Each row of stitching shall consist of 8 to 14 stitches per 5.0 cm. Thread used for seaming shall be polyester. The fabric form shall be customized in factory as per site geometry or profile and then shall be supplied at site in the form of panels consisting of multiple mill width of the fabric form along with baffles and cables installed inside the fabric form. Each such panel shall be connected with the adjacent panel by using Industrial Zipper. In-situ stitching or sewing between panels shall not be allowed. The apron shall be integrated with large sized armor unit at the riverside end to facilitate launching, if any.

Baffles shall be installed at predetermined mill width intervals to regulate the distance of lateral flow of fine aggregate concrete. The baffles shall be designed to maintain a full concrete lining thickness along the full length of the baffle. The baffle material shall be nonwoven filter fabric. The grab tensile strength of the filter fabric shall be not less than 350 N when tested in accordance with ASTM D 4632.

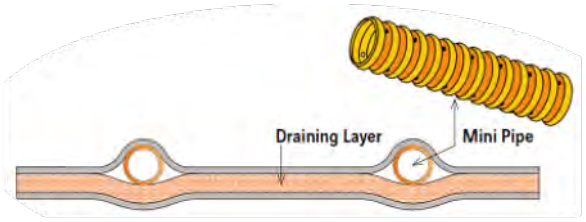
Cables in AB mat shall be galvanized steel cables of minimum 6 mm diameter and the breaking strength of the cable shall not be less than 30 kN. The cables shall be laid in both directions of the mat when it is used as launching apron and the cables shall be laid in one direction when the mat is used for the protection of slope or riverbank.

Fine aggregate concrete shall consist of a proportioned mixture of Portland-Pozzolana cement, fine aggregate (sand) and water. The consistency of the fine aggregate concrete delivered to the concrete pump shall be proportioned and mixed as to have a flow time of 9-12 seconds when passed through the 19-mm orifice of the standard flow cone that is described in ASTM C 939. Additional Pozzolana and/or admixtures may be used with the approval of the Engineer-in-charge. The water/cement ratio varies with the exact granulometry of the fine aggregate (sand) and shall be determined by the ready-mix manufacturer using the above referenced flow cone. Fly ash can be used to reduce the cement consumption.

The fabric forms shall be kept dry and wrapped such that they are protected from the elements during shipping and storage. If stored outdoors, they shall be elevated and protected with a waterproof cover that is opaque to ultraviolet light. The fabric forms shall be labeled as per ASTM D 4873.

Drainage behind TechRevetment lining: One layer of multi-linear geocomposite drainage with mini pipes

shall be placed behind the AB TechRevetment lining from HFL to LWL level for better drainage during rapid drawdown.



Specification of multi-linear geocomposite drainage with mini pipes shall be as under:

Table 15.22 Specification of multi-linear geocomposite drainage with mini pipes

Characteristics Value	Standards	Reference		Value	Unit
Mechanical characteristics					
Mass per unit area	NF EN 9864	Geotextile		369	g/sq.m
Thickness	NF EN 9863 -1	Under 2 kPa		4.0	mm
		Under 20 kPa		3.2	
Tensile strength	NF EN ISO 10319	Machine direction		13.9	kN/m
		Cross direction		13.9	
Tensile elongation	NF EN ISO 10319	Machine direction		63	%
		Cross direction		63	
Pyramidal puncture resistance	NF G 38-019			1.8	kN
Dynamic perforation resistance	NF EN ISO 13433			<4	mm
CBR resistance	NF EN ISO 12236			3.4	kN
Mini-pipes characteristics					
Diameter	NF EN 61386-1	Outside diameter		19	mm
Pipe stiffness at 5% deflection	ASTM D2412	0		4000	kPa
Spacing of mini-pipes	1 mini-pipe every one metre widthways				
Hydraulic characteristics					
Opening size	NF EN ISO 12956	Filter layer		77	µm
Water permeability	NF EN ISO 11058	Filter layer		70	l/s/m2
In-plane flow capacity (mini pipes)	NF EN ISO 12958	Gradient i=0.1	Under 20 kPa	0.18	l/s/m
			Under 100 kPa	0.18	
			Under 400 kPa	0.18	
		Under 400 kPa during 100h		0.18	
		Gradient i=0.3	Under 20 kPa	0.32	l/s/m
			Under 100 kPa	0.32	
			Under 400 kPa	0.32	
		Under 400 kPa during 100h		0.32	
		Gradient i=1	Under 20 kPa	0.70	l/s/m
			Under 100 kPa	0.70	
			Under 400 kPa	0.70	
		Under 400 kPa during 100h		0.70	

One layer of non-woven geotextile filter fabric shall be placed behind the AB TechRevetment lining after LWL till the launching apron length. The non-woven geotextile filter fabric shall be made from polypropylene. The minimum mass of the non-woven geotextile shall be 203 grams per sq.m.

(3) Anchorage with Terra Anchor or its equivalent:

The revetment mattress shall be anchored at the top by excavating a trench and laying the mattress followed by filling the trench with M15 grade of concrete. The cables of the revetment mattress shall be anchored into the trench using driven and stressed soil anchors of 3m length and minimum 2MT capacity. The technical specification of the anchor shall be as under;

Stealth Anchor

S.G. Iron casting confirming to IS 1865:1991

Length: 160mm

Width: 57mm

Height: 50mm

Galvanization: Minimum 500 grams per Sqm

Anchor Strand Wire

Construction of strand: 7X19 steel core

Diameter of wire: Minimum 8mm

Ultimate Tensile strength: Minimum 35 KN

Working load: Minimum 23 KN

Galvanization: Minimum 220 grams per Sqm

(4) Measurement and Payment

The payment for AB mattress, multi linear geocomposite drainage and non-woven geotextile shall be made based on the surface area of the materials supplied for laying on the surface of the slope including anchorage, overlaps and apron. The surface area shall be measure in 'Sqm'.

The payment for the fine aggregate concrete shall be made based on the volume of concrete inside the mattress including the cost of cement, fly ash (if any), fine aggregate, machinery required, tools and plants.

The Payment for AB mattress measured in Sqm, including the cost of fine aggregate concrete shall be made based on the surface area of the mattress if analysis includes both items together.

1520 FILTER POINT (FP) FABRIC FORMED CONCRETE LINING

(1) General

Filter Point linings with filtration point (drains) provide an erosion resistant, permeable concrete lining having a cobbled surface and a relatively high coefficient of hydraulic friction in order to reduce water velocity and wave run-up. The spacing of the filter points determines the linings thickness and weight, while the specially designed filter points relieve hydrostatic pressure and reduce applied stress to the fabric form during pumping.

The fabric forms shall consist of woven double-layer, open salvage fabric joined into panels. Fabric shall be woven of high-tenacity, continuous multifilament polyester of which a minimum of 50%, by weight, shall be textured yarn. Partially-oriented (POY), draw-textured, and/or staple yarns shall not be used in the manufacture of the fabric. The fabric forms shall conform to the physical, mechanical and hydraulic requirements as listed in Table 15.24 and reported by an independent geotextile laboratory within ninety (90) days of date of manufacture. The fabric forms shall be free of defects or flaws which significantly affect their physical, mechanical, or hydraulic properties. The material property requirements of Filter Point Fabric are listed below.

Table 15.23 Typical Dimensions and Weight

Product and sizes	FP220	FP300	FP400	FP600	FP800	FP1000	FP1200
Average Thickness, in (mm)	2.2 (56)	3 (76)	4 (102)	6 (152)	8 (203)	10 (254)	12 (305)
Mass per unit area, lb/ft^2 (kg/m^2)	25 (121)	34 (165)	45 (220)	68 (330)	90 (440)	113 (550)	135 (661)
Concrete Coverage ft^2/yd^3 (m^2/m^3)	136 (16.6)	100 (12.2)	75 (9.1)	50 (6.1)	38 (4.6)	30 (3.6)	25 (3.0)
Filter Point Spacing, in (mm)	5 (127)	6.5 (165)	8 (203)	10 (254)	12 (305)	14 (356)	16 (406)

Table 15.24 Property Requirements – Filter Point Fabric

	Test Method	Units	MARV#
Physical Properties			
Composition of Yarns	Not Applicable		Polyester
Mass Per Unit Area (single-layer)	ASTM D 5261	g/m^2	>200
Mass Per Unit Area (double-layer)			>400
Thickness (single-layer)	ASTM D 5199	mm	0.35
Mill Width (Woven)	Not Applicable	m	3.00
Mechanical Properties			
Wide Width Tensile Strength – MD | TD	ASTM D 4595	kN/m	50 | 50
Wide Width Elongation at Break - MD | TD	ASTM D 4595	%	>10 | >10
Trapezoidal Tear Strength - MD | TD	ASTM D 4533	N	350 | 350
CBR Puncture Strength	ASTM D 6241	N	5100
Hydraulic Properties			
	Test Method	Units	MARV# Range
Apparent Opening Size (AOS)*	ASTM D 4751	mm	< 0.8
Water Flow Rate*	ASTM D 4491	l/m^2/min	> 1000

** Handling may vary the above properties in its application*

 # MARV stands for Minimum Average Roll Value and is calculated as the average minus two standard deviations. Statistically, it yields approximately 97.5% degree of confidence that any samples taken from quality assurance testing will meet or exceed the values described above.

Filter Point Fabric forms shall consist of double-layer woven fabric joined together by spaced, interwoven filter points to form a concrete lining with a deeply cobbled surface appearance. Filter points shall be formed by interweaving the double-layer fabric to form water permeable drains and attachment points for the control of concrete lining thickness. The interweaving of the fabric layers shall form an area of double density, high strength, and single-layer. All filter points shall be cross shaped and shall have twill weave centers designed to function as drains to relieve hydrostatic uplift pressure. The average thickness shall be as per design.

Mill widths of fabric shall be a minimum of 3.0 m. Each selvage edge of the top and bottom layers of fabric shall be reinforced for a width of not less than 34 mm by adding a minimum of 6 warp yarns to each selvage construction. Mill width rolls shall be cut to the length required, and the double-layer fabric separately joined, bottom layer to bottom layer and top layer to top layer, by means of sewing thread, to form multiple mill width panels with sewn seams on not less than 2.90 m centers.

Fabric form panels shall be factory-sewn, by jointing together the layers of fabric, top layer to top layer and bottom layer to bottom layer, into predetermined custom sized panels. Sewn seams shall be downward facing as shown on the Contract Drawings. All sewn seams and zipper attachments shall be made using a double line of U.S. Federal Standard Type 401 stitch. All seams sewn shall be not less than 100 lbf/inch when tested in accordance with ASTM D 4884. Both lines of stitches shall be sewn simultaneously and

be parallel to each other, spaced between 6.3 mm to 19 mm apart. Each row of stitching shall consist of 8 to 14 stitches per 5.0 cm. Thread used for seaming shall be polyester. The fabric form shall be customized in factory as per site geometry or profile and then shall be supplied at site in the form of panels consisting of multiple mill width of the fabric form along with baffles. Each such panel shall be connected with the adjacent panel by using Industrial Zipper. In-situ stitching or sewing between panels shall not be allowed.

Baffles shall be installed at predetermined mill width intervals to regulate the distance of lateral flow of fine aggregate concrete. The baffles shall be designed to maintain a full concrete lining thickness along the full length of the baffle. The baffle material shall be nonwoven filter fabric. The grab tensile strength of the filter fabric shall be not less than 350 N when tested in accordance with ASTM D 4632.

The fabric forms shall be kept dry and wrapped such that they are protected from the elements during shipping and storage. If stored outdoors, they shall be elevated and protected with a waterproof cover that is opaque to ultraviolet light. The fabric forms shall be labeled as per ASTM D 4873.

Fine aggregate concrete shall consist of a proportioned mixture of Portland-Pozzolana cement, fine aggregate (sand) and water. The consistency of the fine aggregate concrete delivered to the concrete pump shall be proportioned and mixed as to have a flow time of 9-12 seconds when passed through the 19-mm orifice of the standard flow cone that is described in ASTM C 939. Additional Pozzolana and/or admixtures may be used with the approval of the Engineer-in-charge. The water/cement ratio varies with the exact granulometry of the fine aggregate (sand) and shall be determined by the ready-mix manufacturer using the above referenced flow cone. Fly ash can be used to reduce the cement consumption.

Drainage behind TechRevetment lining: One layer of non-woven geotextile filter fabric shall be placed behind the TechRevetment lining. The non-woven geotextile filter fabric shall be made from polypropylene. The minimum mass of the non-woven geotextile shall be 203 grams per sq.m.

(2) Measurement and Payment

The payment for FP mattress and non-woven geotextile shall be made based on the surface area of the materials supplied for laying on the surface of the slope including anchorage, overlaps and apron. The surface area shall be measure in ‘sq.m’.

The payment for the fine aggregate concrete shall be made based on the volume of concrete inside the mattress including the cost of cement, fly ash (if any), fine aggregate, machinery required, tools and plants.

The Payment for FP mattress measured in Sqm, including the cost of fine aggregate concrete shall be made based on the surface area of the mattress if analysis includes both items together.

1521 EROSION CONTROL MAT

(1) Scope

The work covers the use of geosynthetic mats for control of erosion of slopes including supplying and laying the mat, spreading soil and seeding to promote the design of vegetation, as per design, drawing and these specifications.

(2) Material and Strength Requirements

Geosynthetic mats shall be a three-dimensional structure consisting of UV stabilized non-degradable polypropylene, polyethylene, nylon or similar polymer fibers that are extruded or heat bonded at the contact points to provide a dimensionally stable matrix for soil erosion protection. A tension element, i.e., a reinforcing element like Geogrid or steel wire mesh shall be included along with the three-dimensional polymeric mats to provide strength against erosive forces, if specified in the contract

The tensile strength requirements for non-reinforced and reinforced three-dimension geosynthetic mats shall meet the minimum requirement as specified in Table 15.25 and Table 15.26 respectively.

(3) Installation

Prior to lying of geosynthetic mat on the slope, the surface shall be properly prepared, cleaned and dressed

to the specified lines and levels as shown on the drawings. Specified trench keys along the crest and at the bottom of slope area shall be provided to fix the geosynthetic mat in the ground. In case the soil is not fertile, it shall be mixed with suitable amounts of fertilizer or seeds.

Table 15.25: Tensile Strength Requirement for Normal (Non-Reinforced) Three-Dimensional Geosynthetic Mat for Erosion Control Application (Less Severe Environmental Condition)

Property	Test method	Units	Minimum Average Roll value
Tensile strength requirement (For slopes less than 60°)	ASTM D 5035	kN/m	2
Ultraviolet stability at 500h, Retained strength percentage with respect to original strength	ASTM D 4355	%	80
Thickness	ASTM D 6525	mm	6.5
Mass per unit area	ASTM D 3776	gm/m^2	350

Table 15.26: Tensile Strength Requirement for Reinforced Three-Dimensional Geosynthetic Mat for Erosion Control Application (Severe Environmental Conditions)

Property		Test method	Units	Minimum average Roll value
Tensile strength requirement	For Slopes up to 60°	ASTM D 5035	kN/m	10
	For Slopes up to 80°			35
Ultraviolet stability at 500h, Retained strength percentage with respect to original strength		ASTM D 4355	%	80
Thickness		ASTM D 6525	mm	12
Mass per unit area of the composite		ASTM D 3776	gm/m^2	500

The work of laying the mat shall begin at the top of the slope providing anchor blankets in a 300 mm deep and 300 mm wide trench and anchoring with staples/pins. The mat shall then be unrolled down the slope in the machine direction. The blanket shall not be stretched but shall have full contact with the soil. The blanket shall be anchored using staples or stakes.

Edges of adjacent parallel rolls shall be overlapped by approximately 100 mm to 120 mm and anchored with staples at 600 mm to 800 mm spacing depending on the slope. When blankets have to be spliced, the upper blanket end shall be placed over lower blanket end (shingle style) with 300 mm overlap and anchoring with two staggered rows of staples at 300 mm spacing.

A minimum cover of soil shall be spread followed by spreading the seeds and fertilizer.

In the absence of rain, blankets shall be regularly watered for viable growth till vegetation sustains on its own.

If any damage due to heavy downpour is noticed, suitable corrective measures shall be taken immediately.

Gully formations, if any, shall be suitably corrected depending upon the site condition.

The treated area shall be protected from the movement of cattle (goat, sheep & cow).

Grazing shall be avoided till the vegetation sustains on its own

(4) Measurement and Payment

The geosynthetic mat shall be measured in square meter as per planned dimensions with no allowance for overlapping at joints, anchoring at toe and crest of the slope.

Geosynthetics mat shall be paid at the respective contract unit rate which shall be full and final compensation for the cost of compliances of all requirements specified in Clause, 1521 in addition to those specified in Clause 115.

1522 STEEL WIRE GRID

(1) General

The Steel grid System is an innovative complete system for rockfall mitigation and slope consolidation works. The Steel grid System combines a high strength steel wire mesh geocomposite which is used in conjunction with anchor plates, specific U-bolts and mesh connectors. The Steel grid mesh is a composite of double twisted steel wire hexagonal mesh with high tensile strength steel cables, woven into the mesh during the manufacturing process.

The high-level corrosion protection for the steel wire mesh and ropes and for the accessories makes the Steel grid System ideal for rockfall protection in all continental environments.

(2) Material

High-strength reinforced composite steel wire mesh/panel with a minimum longitudinal tensile strength of 160 kN/m and puncture resistance of 130kN at maximum displacement of 45 cm, steel ire/rope/high strength rope shall be heavily Zn+5% Al Class A conforming to EN 10244-2 and mesh opening shall not be more than 125mm, including top and bottom support rope, lateral wire rope cable anchors at top and bottom, lacing wire rope, connection clips required to connect the nets and all accessories such as U-clamps, including safety, all other ancillary works, material etc, complete at the easily accessible location including top and bottom.

Equivalent or Higher specifications product will Technically Evaluated and accepted.

For faster installation and better adherence over undulated slope face, high resistance geocomposite steel wire mesh/panel should be single composite product, and mesh opening shall not be more than 125mm. The high resistance steel wire mesh geocomposite shall confirm properties indicated in Table 15.27. All tests on the mesh and lacing wire/wire rope must be performed prior to manufacturing the mesh.

Table – 15.27: High Resistance Geocomposite Steel wire mesh/panel should meet the following minimum strength requirements:

Sr. No.	Strength Parameter	Value (minimum)
01	Longitudinal Tensile Strength of High Resistance Geocomposite steel wire mesh/panel	160kN/m
02	Puncture Resistance of High Resistance Geocomposite steel wire mesh/panel	130kN at maximum displacement of 45 cm

*** *The above parameters shall meet the requirements as per the test procedures defined in IS/ISO 17746.*

Material Technical Performance Requirements:

a. The High Resistance Geocomposite steel wire Mesh/panel should have minimum tensile strength of 160kN/m in longitudinal direction as per the test procedures defined in ISO 17746.

b. Under punch test with the standard / established procedure the system of High Resistance Geocomposite Steel wire mesh/panel should be able to bear minimum resistance of 130 KN with maximum displacement up to 45cm as per the test procedures defined in ISO 17746.

(3) Measurement and Payment

The measurement shall be in Sq.m of Area of High Resistance Steel Wire Mesh Geocomposite supplied.

Payment shall be made as per contract unit rate as specified in the contract.

1523 SELF-DRILLING ANCHOR

(1) General

The Self Drilling Anchor system is comprised of a hollow threaded anchor bar with a sacrificial drill bit that

performs drilling, anchoring and grouting in a single operation.

The SDA shall be designed and arranged in order to stabilize in-situ strata. The grout shall be made of OPC min. grade 43 & above with suitable admixtures. The exposed portion of SDA, nuts and bearing plates shall have corrosion protection coating as per project requirement.

Drilling shall be carried out by suitable equipment. Diameter of SDA shall be 32 mm with sacrificial drill bit of min.76mm dia. The SDA shall be made of yield strength of min. 550 N/mm2 and yield load of min. 230kN. The SDA rod shall be continuously threaded. For convenience of installation, appropriate arrangement (coupler) shall be made to connect two smaller lengths of SDA to achieve the required length.

(2) Installation

(a) The SDA is driven in the required position with help of sacrificial drill bit at the bottom of the anchor bar which facilitates in drilling the hole. The diameter, length and spacing of SDA shall be as specified. Anymore / lesser length or spacing of anchoring/nailing shall be carried out as per site condition and as directed by engineer-in-charge.

(b) The grout is pumped through the hollow bar during the drilling process. Grouting shall be done by using OPC min. grade 43 & above along with addition of suitable admixture. Mixing shall be done along with potable water so as to form the cementitious paste.

(c) The base plates of size (min.) 200mm x 200mm x 10 mm shall be placed at rock interface for tightening the nuts.

(d) The facia (if applicable) shall be installed in front and connected to the steel rods with base plate and nuts.

Following equipment deployed on site

1) Grout agitator

2) Compressor – 450 to 600CFM

3) Drilling equipment percussion/rotary type

Expansive plasticizing agent for cement grouts shall be used, typical brand name DR. FIXIT PIDICRETEAM is a shrinkage compensating grout admixture for pressure grouting.

(3) Special requirement

The agency must have experience in working in steep slopes including surface anchoring for a depth of at least 3m. The agency should also have good experience in drilling and grouting works on steep slopes of more than 100m in height.

(4) Measurement and Payment

The measurement of SDA shall be in running meter as specified in BOQ.

Payment shall be made as per contract unit rate as specified in the contract.

1524 ROCK FALL BARRIER

(1) General

Rockfall barriers are made of high-quality carbon steel or stainless steel, including steel wire rope net, steel ring net, tecco mesh, spider spiral rope mesh, chain link wire mesh and hexagonal wire mesh. With galvanized, powder coated or PVC coated surface, they're corrosion and rust resistant. The common rockfall barrier combination is steel wire rope net with chain link mesh, it can be used as active or passive rockfall barrier for slope or mountain protection to minimize the impact of natural disasters, such as landslide, debris flow and so on.

(2) Material

Material Technical Performance Requirements:

The dynamic Rockfall Barriers shall be approved “Category A” barriers as per EAD (European Approval Document EAD 340059-00-0106(previously known as ETAG 027)).

Specification of The Materials To Be Used:

The flexible rockfall barrier should have pass through the dynamic crash test as per EAD 340059-00-0106 (previously named as ETAG 027) by an independent institute for energy level of 1500KJ/3000KJ/5000KJ capacity in crash test and passed for a category “A” having residual height more than 50% of the nominal height. The flexible high resistance rock fall barrier should have kinetic energy absorption capacity (without any breakage) of 1500KJ/3000KJ/5000KJ and having an interception height of 5m/6m/7m.

The dynamic barrier shall consist of:

- Hot dip galvanized steel posts
- Interception structure made up of to catch the small debris material.
- Upper and lower longitudinal cables, upslope bracing cables, lateral bracing cables, ground cables and downslope bracing cables (if required) with a tensile strength not lower than 1770 N/mm2
- Energy absorbing system consisting of energy dissipating devices installed on the bracing cable or on the perimeter of the interception structure
- Connection of the cables by means of ferrules (pressed in the workshop) or U-bolt wire rope grips according to EN 13411.

The structure shall be suitable for installation on any type of terrain and slopes. All the metallic components shall be protected against corrosion with zinc galvanization in accordance with:

- Steel wire ropes according to EN 10264-2 (class A)
- Supporting structure (steel posts and base plates) protected by hot dip zinc coating according to EN ISO 1461
- Wire of the net according to EN 10244-2 (Class A)
- U-bolt wire rope grips hot dip zinc coated according to ASTM A153
- Shackles (if any) hot dip zinc coated according to EN ISO 1461
- Fasteners (bolts and nuts) hot dip zinc coated according to EN ISO 10684
- Anchor bars hot dip zinc coated according to EN ISO 1461
- Electroplated coatings for minor components according to EN ISO 4042.

Materials shall be confirmed to the following standards:

- EAD 340059-00-0106(previously named as ETAG 027) – Dynamic Crash Test
- Barrier shall meet the quality certification standard UNI EN ISO 9001
- Cables – Tensile Strength shall not be less than 1770N/mm^2
- Energy dissipaters - energy absorption by deformation
- EN 13411-5-Clamps/Ferrules / U bolt
- EN10264 –2-Steel wire rope Zn coating
- EN ISO 1461- Zn coating of Post and base plate
- EN 10223-3 and EN 10244 -2 -Double Twisted Hexagonal Net tensile strength and Zn coating
- EN 10025 –2- Hot Rolled Products

The structure shall be suitable for installation on any type of terrain and slopes. All the metallic components shall be protected against corrosion. The system shall have energy dissipators/braking system which should be able to help dissipate the impact energy by deformation and not by friction.

Testing and Acceptance criteria for Quality Control:

The Category A dynamic Rockfall Barriers shall be supplied along with the approved test certificate mentioning residual height and capacity and have passed dynamic impact test as per EAD 340059-00-0106(previously named as ETAG 027).

(3) Measurement and Payment

The rockfall barrier shall be measured in running meter.

Payment shall be made at contract unit rate as specified in the contract.

1525 RHOMBOIDAL WIRE ROPE PANEL/MESH

(1) General

The rockfall protection system shall be as per IRC Highway Research Board Special Report-23 to be used for high hazard locations and should have corrosion protection heavily Zn Class A coating, to prevent corrosion effect at rockfall protection system.

(2) Material Specifications

Rhomboidal shaped cable/wire rope panels with a minimum tensile strength of 230kN/m and punch strength of 370kN with max. displacement of 35cm, heavily Zn class A coated conforming to EN 10244-2 with a suitable connection at each intermediate and end junctions including top and bottom support rope, lateral wire rope cable anchors at top and bottom, lacing wire rope required to connect the nets and all accessories such as U-clamps, including safety, all other ancillary works, material etc, complete at the easily accessible location including top and bottom.

Equivalent or Higher specifications product will Technically Evaluated and accepted.

Table – 15.28: The wire rope cable panel should meet the following minimum strength requirements:

Sr. No.	Strength Parameter	Value (minimum)
01	Tensile Strength of cable Panel	230KN/m
02	Puncture Strength of Cable Panel	370 KN at maximum displacement of 34cm

**** The above parameters shall meet the requirements as per the test procedures defined in IS/ISO 17746.*

Material Technical Performance Requirements:

a) The established system should be able to increase the bearing capacity during punch test/ any accepted method of testing material. Under punch test with the standard / established procedure the system of wire rope cable panel with suitable connection at each intermediate and end junction should be able to bear minimum resistance of 370 KN with maximum displacement up to 34cm as per the test procedures defined in IS/ISO 17746.

b) The wire rope cable panel with suitable connection at each intermediate and end junction should have minimum tensile strength of 230kN/m as per the test procedures defined in IS/ISO 17746.

(3) Measurement and Payment

The measurement shall be based on Sq.m of Area of cable/wire rope panels supplied.

Payment shall be made at contract unit rate as specified in the contract.

NOTE : If in any item , Commercial Brand name has been defined, then equivalent product can be used.

SECTION 1600: TUBEWELL DRILLING WORK

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1601 SCOPE OF WORK

This Section covers guidelines, specifications, and standard procedures of the Department of Water Resources and Irrigation (GWRI) for the exploration and development of groundwater for irrigation purposes. It provides guidelines and procedures for the selection of well construction methods for investigation and development of irrigation tube wells required or recommended supporting documentation of these activities. This Section includes (1) documentation needed for well files, field folders, and electronic files; (2) criteria and information needed for the selection of water-supply and irrigation wells, including site inventory and data collection during field reconnaissance; and (3) criteria and preparation for installation of investigation wells, including the effects of equipment and materials on the chemistry of ground-water samples, a summary of drilling and coring methods, and information concerning well completion, development, and disposition.

1602 GENERAL

This Manual with specifications (MS) provides hydrogeological guidelines for the Hydrogeologists and Groundwater development offices (HG) under the Ministry of Energy, Water Resources and Irrigation (MoEWRI), Government of Nepal (GON) in the planning, installing, and reporting of alluvial and bedrock tube well borings, and monitoring wells at various geological terrains. These guidelines are a compilation of those procedures necessary for the acquisition of environmentally representative hydrogeological data and samples, using conservative methods documented in a comprehensive manner.

1. Applicability

a. This MS applies to all government, and semi-government offices related to the investigation and development of water wells and their contractors including hydrogeologists, geologists, and engineers related to the field and similar activities.

b. The specific application of and adherence to these guidelines must be tailored to each project as a function of the water well of concern; local geohydrology setting; hydrological judgment; available resources; applicable regulatory requirements; policy and guidance; public concerns; and project mission.

2. References

This MS is based on and derived from international standards and available standard local materials and practices. Appendix contains a list of those publications referenced by and relevant to this manual.

3. Terminology

Providing program-level technical guidance in his administrative situation requires the guidance to be specific while allowing any field activity to adapt the guidance to its needs. The intent is to foster the defense of variances, not the defense of recommended methods and procedures. This approach is warranted to provide the employer with compatibility while allowing functional flexibility. The following three terms are introduced: **the field activity (FA); the field drilling organization (FDO) or Ground-Water User Association (GWUA);** and the drilling and well installation plan. Generically, these terms refer to a client-contractor-contract relationship. This relationship can be applied to both in-house and contracted efforts, thereby providing consistency for the geotechnical portion of the involvement of hydrogeologists and associated organizations. Definitions are alphabetically ordered.

(1) Field Sampling Plan (FSP): The FSP is contained within the Sampling and Analysis Plan (SAP), and describes the drilling and well installation plan. The plan specifies the field effort; for example: borehole/well/sample locations, depths, equipment, materials, procedures and alternatives, quality control measures, and other topics required by the responsible FA and Implementation is by the FDO/GWUA.

(2) Field activity (FA): The drilling works are mainly supervised by the personnel of the groundwater development authorities such as the Department of Water Resources and Irrigation (DWRI) and its branch offices, project offices, laboratory, or the agency assigned by the government body or by the field Hydrogeologist/Assistant- Hydrogeologist of FDO/GWUA approved by the authorized government body,

otherwise acquiring the responsibility to administer a contract, agreement, or in-house investigation drilling procedure to research, investigate, design, and/or construct a project involving groundwater irrigation.

(3) Field drilling organization (FDO) or Ground-Water User Association (GWUA): That office within the HG or contracted by the HG is responsible for the execution of the drilling plan. In a contracted arrangement, the prime contractor is regarded as the FDO. Sub- contractors, even though they may physically perform the fieldwork, are the responsibility of the prime contractor, whom the HG holds contractually accountable.

(4) Hydrogeological data quality management (HDQM): The development and application of those policies and procedures required to obtain and utilize accurate and representative geotechnical information throughout the entire Groundwater Extraction (GE) project cycle, from predesign investigations to post construction monitoring.

(5) Monitoring/Investigation well (MW) : A monitoring well is a device designed and constructed for the acquisition of groundwater samples that are representative of the chemical quality of the aquifer adjacent to the screened interval, unbiased by the well materials and installation process; and which, if so designed, provides access to measure potentiometric head across the screened interval.

(6) Redevelopment/Rehabilitation of well (RoW) : A procedure that restores the original or near original pumping capacity to an existing well by the removal of sediment, precipitation, flocculent, surface run-in, or other built-up materials from within that well.

(7) Screened interval (SI): That portion of a well that is directly open to the host environment/aquifer by way of openings in the well screen.

(8) Site safety and health plan (SSHP): A project- unique document approved by the responsible FA for FDO compliance. The plan includes the identification of hazardous substances present, recommended action upon encountering those substances, project/site safety requirements, organizational safety responsibilities, and the identification of supporting health and safety activities.

(9) Well development (WD): A procedure that locally improves or restores the aquifer's hydraulic conductivity, and well capacity, and removes well drilling fluids, muds, cuttings, mobile particulates, and entrapped gases from within and adjacent to a newly installed well.

(10) Supporting documentation (SD):

Investigation and Development of groundwater require careful and complete documentation of site information and criteria and methods used for the selection installation and development of wells. Such documentation is integrated throughout each well-selection and well-installation process. Systematic documentation is a basic component of quality assurance and often aids interpretation of groundwater data for future studies. Documentation involves the establishment of a well file that includes electronic and paper records for each well, compilation of available information, the addition and verification of information at the field site, and record-keeping during each phase of the study.

This section summarizes the types of documentation generally required for the well file and for that part of the file used during field visits (the field folder) (fig. 16.1).

Figure 16.1. Example of a well-information checklist for a well file.

WELL-INFORMATION CHECKLIST, Page 1 of 2

Well Identification

Project name and identification number: _____ Latitude-longitude:_____

Sequence number: _____ Other site or well ID:_____Location: _____

WUA Name:_____ Contact Person:_____ Contact Phone:_____

Indicate well type: Shallow / Deep — Irrigation / investigation / Monitoring / Other _____

Item in well file — Date item filed

Well Location

Latitude and longitude	_____
Well-location map(s)	_____
Site-sketch map	_____
Written description of location	_____
Well-casing elevation	_____
Photographs of well and vicinity (with measuring/sampling points identified)	_____
Land-use/land-cover	_____

Electronic Files

Reports	_____
Sample logs	_____
Time Logs	_____
Resistivity, Self-Potential	_____
Gamma-Gamma	_____
Core	_____

Criteria Used for Well Selection or Installation

Drilling method selection (describe criteria in file)	_____
Well Selection (describe criteria in file)	_____
Well Installation (describe criteria in file)	_____

WELL-INFORMATION CHECKLIST, Page 2 of 2

Item in well file	Date item filed
Well Installation	
Well-drilling record Driller's log Lithologic log Cuttings Cores	
Well-completion record Well-development record	
Well-maintenance checks: (list types)	
Others	
	_____
Pumping schedule/history	_____
Type of pump in well and depth, HP, model	_____
Water-Level and Water-Quality Data	
Description of measuring point for water levels:	_____
Water-level measurements - static:	_____
Water-level measurements -dynamic :	_____
Other Data Related to the Well Site	
Aquifer tests: (list types)	_____
Geophysical logs: (list types)	_____
Other:	_____

1603 SITE CONSTRUCTION OF BOREHOLES AND WELLS:

1. Site Reconnaissance

Site visits are suggested for project hydrogeological personnel as early as practical in the planning for any subsurface exploration. The purpose of this reconnaissance is to evaluate physical site conditions and logistical support availability. Items of interest would include geologic and geographic settings, site access, electricity, water sources, proximal utilities, service areas, sample shipment facilities, and potential hazards. Application of this knowledge will contribute to enhancing the technical approach and cost realism for subsequent project development.

2. Locations and Quantities

The locations and quantities of boreholes and wells should be selected to effectively ascertain desired geologic, hydrologic, and/or chemical parameters. The number of borings or wells specified in the drilling plan should not be altered without coordination with the FA. The drilling and well installation plan should permit relocations when necessitated by proximal utilities or drilling difficulties. The criteria for selection of the new location(s) should be included as a portion of the drilling plan and should indicate when coordination would be required with the FA.

3. Well Construction Method Selection and Drilling Operation

The FDO/GWUA should comply with all security policies at the project site. The FDO/GWUA is responsible for securing its own equipment, mobilization to the site, and minor site clearance. The FDO/GWUA should address any special situations in the drilling plan prior to the start of construction work. If site conditions are out of hand, FDO/GWUA should consult with the employer's office before hand, otherwise, they have to take sole responsibility.

A. Drilling Safety and Underground Utility Detection

When drilling in areas of known or suspected hazardous materials, appropriate health and safety precautions should be implemented and liable to FDO/GWUA (Ref: OSHA documentation). The FDO/GWUA should determine all applicable regulations, requirements, and permits with regard to drilling safety and underground utility detection. These items should be included in the safety plan. The safety plan should be approved by the FA prior to any drilling.

B. Permits, Licenses, Professional Registration, and Rights-of-Entry

The FA should be responsible for identifying all applicable permits, licenses, professional registration, rights-of-entry, and applicable state and local regulatory procedures for drilling, well installation, well decommissioning/ abandonment, and topographic surveying (to include any requirements for the submission of well logs, samples, etc.). Acquisition and submission of these items to state or local authorities should be coordinated between the FA and FDO/GWUA with the responsibilities of each specified in the drilling plan and should be approved and authorized by HG, The need for any rights- of entry should be specified in the drilling plan along with the organization(s) responsible for their acquisition.

C. Site Hydrogeologist/ Assistant Hydrogeologists/ Site In-Charge (SIH)

A "Site hydro-geologist" (defined as an earth science professional with a college degree in geology and branch fields such as hydrogeology; has experience in hydrogeological investigation, well construction projects, soil and rock logging, and well installation), should be present at each operating drill rig. This geologist should be responsible for all types of logging; acquiring (and possibly shipment) samples; monitoring drilling operations; recording water losses/gains and groundwater data; preparing the boring logs and well diagrams; and recording the well installation and decommissioning procedures conducted with that rig. Each site geologist should be responsible for only one operating rig along with a minimum of two field assistant hydrogeologists for minor operations and necessary field tools provided by their employer (FDO/GWUA/HG).

The geologist should have onsite enough tools, forms, and professional equipment such as a sieve and resistivity logging instrument in operable condition to efficiently perform the duties as outlined in this manual

and other relevant project documents. Items in the possession of each site geologist should include, as a minimum, a copy of this manual, a copy of the approved drilling and well installation plan, log forms, the approved safety plan, a 10-power (minimum) hand lens, and a measuring tape (weighted with stainless steel or chemically stable, nonmetallic material) long enough to measure the deepest boring/well within the project, heavy enough to reach that depth, and small enough to readily fit within the appropriate annulus or opening.

Each site geologist should also have onsite a water-level measuring device (preferably electrical), pH and electric conductivity meters, a turbid meter, a thermometer, an instrument for measuring dissolved oxygen, and materials necessary to prepare the samples for storage or shipment. At some sites, the geologist may be also responsible for monitoring gases during drilling. If so, the geologist should have the necessary instruments and be proficient in their use and calibration as per site conditions.

D. Equipment

(I) Condition:

All drilling, sampling, and supporting equipment such as air-compressor and pump testing types of equipment, brought to a site should be in operable condition and free of leaks in the hydraulic, lubrication, fuel, and other fluid systems where fluid leakage would or could be detrimental to the project effort. All switches (including safety switches), gages, and other electrical, mechanical, pneumatic, and hydraulic systems should be in a safe and operable condition prior to arrival onsite.

(II) Cleaning

All drilling equipment should be cleaned with steam or pressurized hot water before arriving at the project installation/site. After arrival but prior to project commencement, all drilling equipment including rigs, support vehicles, water tanks (inside and out), augers, drill casings, rods, samplers, tools, recirculation tanks, etc., should be cleaned with steam or pressurized hot water using water at the installation decontamination point. A similar cleaning should also occur between each boring/well site. After the onsite cleaning, only the equipment used or soiled at a particular boring or well should need to be recleaned between sites and checked and approved by SIH. Prior to use, all casings, augers, recirculation and water tanks, etc., should be devoid both inside and out of any asphaltic, bituminous, or other encrusting or coating materials, grease, grout, soil, etc. Paint, applied by the equipment manufacturer, may not have to be removed from drilling equipment, depending upon the paint composition and its contact with the environment and contaminants of concern. All equipment should be decontaminated before it is removed from the project site. Waste solids and water from the cleaning/decontamination process should be properly collected and disposed of.

1604 DRILLING METHODS

a. Objective: The objective of selecting a drilling method for monitor well installation is to use that technique which

1. Provides representative data and samples.
2. Eliminates or minimizes the potential for subsurface contamination and/or cross-contamination.
3. Minimizes drilling costs.

b. Methods: The type of equipment required to create a stable, open, vertical borehole for the installation of an irrigation well depends upon the site geology, hydrogeology, and the intended use of the well. Engineering and geological judgment and some knowledge of subsurface geological conditions at the site are required for the selection of the appropriate drilling method(s) utilized for drilling the irrigation boreholes and monitoring wells. The most common methods of selection of drilling methods based on various parameters for the construction of water wells are listed in Table 1, which presents types of drilling methods according to local practices, terrain, and field conditions (Modified after, ASTM D 6286, Driscoll (1986)). Appropriate drilling methods for investigating and installing irrigation wells at a site may include any one or

a combination of several of the following methods. Whenever feasible, it is advisable to utilize drilling procedures that do not require the introduction of water or drilling fluids into the borehole, and that optimize cuttings control at ground surface. Where the use of water or drilling fluid is unavoidable, the selected fluid should have as little impact as possible on the environment. In addition, care should be taken to remove as much drilling fluid as possible from the well and the surrounding formation during the well development process. It is recommended that if an air compressor is used, it be equipped with an oil air filter or oil trap to minimize the potential for chemical alteration of groundwater samples collected after the well is installed. Geophysical surveys also should be used, when possible, to aid in the selection of a drilling method. Surface geophysical methods, such as seismic surveys and electrical resistivity and electromagnetic-conductance surveys, can be valuable particularly when distinct differences in the properties of contiguous subsurface materials are indicated.

Borehole-geophysical methods, such as fluid temperature and resistivity, natural gamma, gamma-gamma, neutron, sonic velocity logging, caliper logging, and borehole camera logs (fracture logging), are useful to confirm specific subsurface geologic conditions. Borehole television logs allow a visual study of existing borehole-wall conditions, as well as viewing casing conditions in a cased borehole. Acoustic borehole camera logs can exhibit fracturing in the borehole. The orientation of the fractures, as well as the extent of fracture occurrence, can be determined using acoustic camera logs. Natural gamma logs, when used in conjunction with the original driller's logs, are useful particularly for determining lithology in existing cased wells.

c. Minimum Distance Requirements

The standard minimum distance requirements before construction of well are as follows.

- 10 m (33 ft.) from a watertight septic tank
- 50 m (165 ft.) from sewage effluent discharge to the ground
- 100 m (329 ft.) from a sewage lagoon
- 50 m (165 ft.) from above-ground fuel storage tanks
- 3.25 m (11 ft.) from existing buildings
- 2 m (7 ft.) from overhead power lines; if the line conductors are insulated or weatherproofed and the line is operated at 440 volts or less
- 6 m (20 ft.) from overhead power lines if the well: does not have a submersible pumping system; has a PVC or non-conducting pipe pumping system.
- 12 m (40 ft.) from overhead power lines for all other well constructions
- 500 m (1,641 ft.) from a sanitary landfill, modified sanitary landfill, or dry waste site.

d. Selection of well drilling methods

All factors affecting both surface and subsurface environment at a specific site require professional judgment and must be considered by the geologist/hydrologist or experienced driller before a drilling method is selected. Significant soil and rock masses and groundwater conditions within a given site should be described and defined, both vertically and horizontally, before drilling. Site planning requires a reconnaissance site investigation that considers access to the drilling site and conditions for setting up the drilling equipment. Following tables (Table 1 and Table 2) provides guidelines for selection of drilling methods based on various parameters.

Table 16.1: Well-Drilling Selection Guide (ASTM D-6286).

Drilling Method	Drilling Fluid	Casing Advance	Type of Material Drilled	Typical Drilling Depth, ft	Typical Range of Borehole Sizes, in in.	Samples Obtainable[B]	Coring Possible	Reference Section
Power auger (Hollow-stem)	none, water, mud	yes	soil, weathered rock	<150	5–22	S, F	yes	6.2
Power auger (Solid-stem)	water, mud	no	soil, weathered rock	<150	2–10	s	yes	6.3
Power bucket auger	none, water (below water table)	no	soil, weathered rock	<150	18–48	S	yes	6.4
Hand auger	none	no	soil	<70 (above water table only)	2–6	S	yes	6.5
Direct fluid rotary	water, mud	yes	soil, rock	>1000	2–36	S, R	yes	7.3
Direct air rotary	air, water, foam	yes	soil, rock	>1500	2–36	S, R, F	yes	7.4
DTH hammer	air, water, foam	yes	rock, boulders	<2000	4–16	R	yes	7.5.1
Wireline	air, water, foam	yes	soil, rock	>1000	3–6	S, R, F	yes	7.6
Reverse fluid rotary	water, mud	yes	soil, rock	<2000	12–36	S, R, F	yes	7.8
Reverse air rotary	air, water, foam	yes	soil, rock	>1000	12–36	S, R, F	yes	7.7
Cable tool	water water table)	yes	soil, rock	<5000	4–24	S, R, F (F–below	yes	8
Casing-advancer	air, water, mud	yes	soil, rock, boulders	<2000	2–16	S, R, F	yes	9
Direct-push technology	none	yes	soil	<100	1.5–3	S, F	yes	10
Sonic (vibratory)	none, water, mud, air	yes	soil, rock, boulders	<500	4–12	S, R, F	yes	11
Jet percussion	water	no	soil	<50	2–4	S	no	12
Jetting	water	yes	soil	<50	4	S	no	12

- *Actual achievable drilled depths will vary depending on the ambient geo-hydrologic conditions existing at the site and size of drilling equipment used. For example, large, high-torque rigs can drill to greater depths than their smaller counterparts under favorable site conditions. Boreholes drilled using air/air foam can reach greater depths more efficiently using two-stage positive-displacement compressors having the capability of developing working pressures of 250 to 350 psi and 500 to 750 cfm, particularly when submergence requires higher pressures. The smaller rotary-type compressors only are capable of producing a maximum working pressure of 125 psi and produce 500 to 1200 cfm. Likewise, the rig mast must be constructed to safely carry the anticipated working loads expected. To allow for contingencies, it is recommended that the rated capacity of the mast be at least twice the anticipated weight load or normal pulling load. B Soil S (Cuttings), Rock R (Cuttings), Fluid F (some samples might require accessory sampling devices to obtain).*

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TABLE-16.2: SELECTION OF WELL DRILLING METHODS (Modified after (ASTM D 6286, Driscoll (1986))

Shallow TW Construction Method	Drilling Principle	Approx. Depth m. (ft)	Advantages	Disadvantages	Drilling Fluid	Formation (Type of Material Drilled)	Common Casing, Screen Material	Filer pack/Sealants
Dug well	Dug well construction employs manual excavation, often using hand tools, ensuring proper lining and protection for groundwater access. The RCC Rings were sunken by scouring the soil materials underneath.	30 (100)	Avoids the use of drilling fluids and lubricants during drilling. Hand Tools and Equipment. Disturbance of geochemical conditions during installation is minimized. A fast and reliable method for the construction of wells for near-surface water tables.	Limited to soft materials such as clay, silt, sand, and fine varieties of gravel. Compact, gravelly materials and rock strata may be hard to penetrate. Generally precludes conventional borehole geophysical logging. The well yields relatively low rates of water. Surface contaminants may be present in Water.	None	Soft materials of alluvial/ residual deposits	RCC rings	None/Cements, Clay
Manual Method: Thokuwa / Hammering / Driven / Hollow Auger and Solid Stem (Machine /Bogie)	Successive 3-6-ft flights of spiral/pointed-shaped drill stems are rotated continuously or hammered with weight on the drill bit to create a hole in the ground. Cuttings are brought to the surface by the turning action of the auger or drill bit.	45 (150)	Fairly inexpensive. Fairly simple and moderately fast operation. Small rigs can get to difficult-to-reach areas. Quick setup time. Can quickly construct shallow wells in firm, noncavey materials. No drilling fluid or lubricants are required. Use of hollow-stem augers greatly facilitates the collection of samples, and continuous sampling is possible. Small-diameter wells can be built inside hollow-stem flights in fine geologic materials.	Depth of penetration is limited, especially in cavey materials. Cannot be used in rock or well-cemented formations. Difficult to drill in cobbles or boulders. The log of the well is difficult to interpret without the collection of split spoons due to the lag time for cuttings to reach the ground surface. Soil samples returned by auger flight are disturbed making it difficult to determine the precise depth from which the sample came. Vertical leakage of water through the borehole during drilling is likely to occur. Solid stem is limited to fine-grained, unconsolidated materials that will not collapse when unsupported. Borehole walls can be smeared by previously drilled clay. With hollow-stem flights, heaving sand can present a problem. May need to add water down-auger to control heaving or wash materials from the auger before completing the well.	Water, mud. dung	Soil, weathered rock	MS, GI, HDPE, PVC Pipes	Coarse sand to Granules / None
Jetting (Dhikuli)	The washing action of water forced out of the bottom of the drill rod clears the hole to allow penetration. Cuttings brought to the surface by water owing up the	15 (50)	Relatively fast and inexpensive. A driller is often not needed for shallow holes. In firm, noncavey deposits where the hole will stand open, well construction is fairly simple. Minimum equipment required. Equipment is highly mobile.	Somewhat slow with increasing depth. Limited to drilling relatively shallow depth, small diameter boreholes. Extremely difficult to use in very coarse materials, i.e., cobbles and boulders. Large quantities of water are required during the drilling process. A water supply is needed that is under enough pressure to penetrate the geologic materials present. The use of water can affect groundwater quality in aquifers. Difficult-to-interpret sequence of geologic materials from cuttings. The	Water, mud. dung	Soil, weathered rock	MS, GI, HDPE, PVC Pipes	Coarse sand to Granules / None

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	outside of the drill rod.			presence of gravel or larger materials can limit drilling. A borehole can collapse if the borehole is uncased in limited depth.				

RCC: Rod, concrete, cement; MS: Mild Steel; GI: Galvanized Iron; HDPE: High Density Poly Ethelene; PVC: Polyvinyl Chloride

TABLE-16.2: WELL DRILLING METHODS (Modified after (ASTM D 6286, Driscoll (1986))

Deep Tube Well Construction Method	Drilling Principle	Approx. Depth m. (ft)	Advantages	Disadvantages	Drilling Fluid	Formation (Type of Material Drilled)	Common Casing, Screen Material	Filer pack and Sealants
Cable-tool (percussion)	The hole was created by dropping a heavy "string" of drill tools into the well bore, crushing materials at the bottom. Cuttings are removed occasionally by the bailer. Generally cashing is driven just ahead of the bottom of the hole; a hole greater than 6 inches in diameter is usually made.	300+ (1,000 +)	Can be used in rock formations as well as unconsolidated formations. Can drill through cobbles and boulders and highly cavernous or fractured rock. Fairly accurate logs can be prepared from cuttings if collected often enough. Driving a casing ahead of the hole minimizes cross-contamination by vertical leakage of formation waters and maintains borehole stability. Recovery of borehole fluid samples is excellent throughout the entire depth of the borehole. An excellent method for detecting thin water-bearing zones of Bhabhar. An excellent method for estimating the yield of water-bearing zones. An excellent method for drilling in soil and rock where the lost circulation of drilling fluid is possible. core samples can be easily obtained. Excellent for the development of a well.	The potential for cross-contaminated samples is very high. Decontamination can be difficult. Heavy steel drive pipe used to keep hole open and drilling "tools" can limit accessibility. Relatively slow drilling method. Heavier wall, larger diameter casing than that used for other drilling methods normally used. The temporary casing can cause problems with the emplacement of an effective filter pack and grout seal. Heaving of unconsolidated sediment into the bottom of the casing can be a problem.	Water	Courser materials (gravels) and rocks	MS, GI, SS, HDPE, PVC Pipes	Gravel/ Grouts, mud and bentonite

Direct fluid rotary or Mud Rotary	Rotating bit breaks formation; cuttings are brought to the surface by circulating fluid (mud). Mud is forced down the interior of the drill stem, out the bit, and up the annulus between the drill stem and hole wall. Cuttings are removed by settling in "mud pit" at the ground surface and the mud is circulated back down the drill stem.	1,500+ (5,000 +)	Drilling is fait quick in all types of geologic materials, hard and soft. The borehole will stay open often from the formation of a mud wall on the sides of borehole by the circulating drilling mud. Eases geophysical logging and well construction. Geologic cores can be collected. Can use casing-advancement drilling method. A borehole can readily be gravel-packed and grouted. Virtually unlimited depths are possible.	Expensive, and requires an experienced driller and a fair amount of peripheral equipment. Completed wells may be difficult to develop, especially small diameter wells, because of mud or filter-cake on the wall borehole. Lubricants used during drilling can contaminate the borehole fluid and soil/rock samples. Geologic logging, visual inspection of cuttings is fair due to the presence of drilling mud. Beds of sand, gravel, or clay may be missed or sample from top of the well can be appear later. Location of water-bearing zones during drilling can be difficult to detect. Drilling fluid circulation is often lost or difficult to maintain in fractured rock, root zones, or in gravels and cobbles. Difficult drilling in boulders and cobbles. The presence of drilling mud can contaminate water samples. Overburden casing usually required. Circulation of drilling fluid through a contaminated zone can create a hazard at the ground surface with the mud pit and cross-contaminate clean zones during circulation.	Water, mud	Alluvial and rocks	MS, GI, SS, HDPE, PVC Pipes	Gravel/ Grouts, mud and bentonite
Reverse Rotary	Similar to the direct hydraulic rotary method except the drilling fluid is circulated down the borehole outside the drill stem and is pumped up the inside, just the reverse of the normal rotary method Water is used as the drilling fluid, rather than a mud, and the hole is kept open by the hydrostatic pressure of the water standing in the borehole.	1,500+ (5,000 +)	Drilling is readily accomplished in soils and most hard rock. Drilling is relatively fast and for drilling large diameter boreholes. The borehole is accessible for geophysical logging prior to the installation of the well. Creates a very "clean" hole, not dirtied with drilling mud. The large diameter of the borehole permits relatively easy installation of an investigation and discharge well. Can be used in all geologic formations. Very deep penetrations are possible.	Drilling through cobbles and boulders may be difficult. Using drilling fluids, polymeric additives, dung, and lubricants can affect the borehole chemistry. A large water supply is needed to maintain hydrostatic pressure in deep holes and when highly conductive formations are encountered. Expensive experience driller and much peripheral equipment required. Hole diameters are usually large, commonly 18 inches or greater. Cross-contamination from circulating water is likely. Geologic samples brought to the surface are generally poor; circulating water will "wash" finer materials from the sample.	Water, mud	Alluvial and rocks	MS, GI, SS, HDPE, PVC Pipes	Gravel/ Grouts, mud and bentonite
Air-Percussion Rotary or Down-the-Hole (DTH) Hammer	Very similar to hydraulic rotary, the main difference is that air is used as the primary drilling fluid as opposed to mud or water with a reciprocating hammer connected to the bit to fracture rock.	600 (2,000)	Very fast penetrations. Useful in all geologic formations. Only small amounts of water are needed for dust and bit temperature control. Cross-contamination potential can be reduced by driving casing. Can use casing-advancement method. Well, development is relatively easy.	Relatively expensive. As with most hydraulic rotary methods, the rig is fairly heavy, limiting accessibility. Overburden casing is usually required. Vertical mixing of water and air creates cross-contamination potential. The hazard posed to the surface environment if toxic compounds are encountered. DTH hammer drilling can cause hydraulic fracturing of the borehole wall. The DTH hammer requires lubrication during drilling. Organic foam additives for cuttings removal may contaminate samples.	Air, water, foam	Alluvial, Boulders and rocks	MS, GI, SS, HDPE, PVC Pipes	Gravel/ Grouts, mud and bentonite

1605 CONSTRUCTION OF WELL AND SELECTION OF DRILLING MACHINERY

(I) Shallow Tube well Construction Methods

Dug Well:

Dug wells are holes in the ground dug by shovel or backhoe. Historically, a dug well was excavated below the groundwater table until incoming water exceeded the digger's bailing rate. The well was then lined (cased) with RCC rings, stones, brick, tile, or other material to prevent collapse. It was covered with a cap of wood, stone, or concrete. Since it is so difficult to dig beneath the groundwater table, dug wells are not very deep. Typically, they are only 3 to 30 meters deep. Being shallow, dug wells have the highest risk of becoming contaminated. Features of Dug Well Construction

- The well should be cased with a watertight material (for example, precast concrete) and a cement grout or bentonite clay sealant poured along the outside of the casing to the top of the well.
- The well should be covered by a concrete curb and cap that stands about a foot above the ground.
- The land surface around the well should be mounded so that surface water runs away from the well and is not allowed to pond around the outside of the wellhead.
- Ideally, the pump for your well should be inside your home or in a separate pump house, rather than in a pit next to the well.

Land activities around a dug well can also contaminate it. Dug wells have been used as a household as well as irrigation water supply source for many years, dug before drilling equipment was readily available or when drilling was considered too expensive and still the best low-cost method of water supply around rural and urban parts of Nepal.

Drilling Machinery: Pickaxe, shovel or backhoe, excavators,

a. Hollow Auger Method:

The hollow-stem continuous-flight auger drilling method can be used for the installation of shallow irrigation wells. The hollow auger flights serve as a temporary casing, which prevents caving and sloughing of the borehole wall while the monitoring-well casing is installed through the hollow auger (see Guide D5784). The hollow-stem auger-drilling method also allows for the utilization of the hollow-stem auger column as a casing for subsequent drilling activities in soils or rock (see Practice D2113). Borehole diameters up to about 55 cm (22 inch.) can be drilled using hollow-stem augers. A well casing can be installed through the hollow stem auger for insertion of casing or other instrumentation, once drilling is complete and prior to removing the augers from the borehole.

Drilling Machinery: Hollow Auger Machinery, Bits, Sampling Box

b. Solid Stem Auger (Bogie Machine/Small Rig) Method:

This method employs a Claw Bit to drive solid stem auger flights into the ground, exerting pressure on the stem's top while rotating it into the soil with the mechanical help of the Bogie machine. The Claw Bit displaces and transports soil upward as drilling progresses through the subsurface lithology. Advantages include swift drilling in clay-rich soils, and reducing time and costs. No circulation fluids are needed, simplifying site clean-up compared to other methods. In stable formations, no casing materials are required. Sampling in semi-consolidated soil formations is facilitated. The method achieves depths exceeding 120 meters / 400 feet in semi-consolidated soils but is unsuitable for loose, sandy formation and uses threaded drill stems of 5-10 ft in length and drill bits up to 2.5 to 7-5/8 inch diameters for the rapid construction of both shallow tube wells and investigation tube wells.

Drilling Machinery: Solid Stem Auger, Drilling Machinery, Bits, Sampling Box, Pump

Minimum Requirements: Small drilling rig up to 120 m drilling capacity, double threaded solid drill stem, drill bits, air compressor up to 7 psi.

c. Driven/Thokuwa/Hammering Manual Method:

The hand-boring set is a simple, manually driven device that works on the basis of percussion. Normally, the bailer/sand pump is used as a drilling instrument. It is a steel pipe with a cutting edge at the lower end and a hook at the upper end, with a thickness of around 2.5 inches. The Small-diameter-driven wells are constructed by driving a good point (drill bit/screens) into the alternate layers of gravel, silt, and sand as subsurface formation. The well point consists of a perforated pipe, with a steel point at its lower end to break through pebbles or thin, hard layers. It is driven deep into the shallow water-bearing formation either by rotating by hammering a weight (sledgehammer) from a height to iron pipes to penetrate the soft-to-hard formation. The depth of the driven well generally does not ordinarily exceed 45 m and their diameters vary from 2.5 to 6.5 inches for hand driven well construction method. Sections of pipes generally 5-10 feet in length are added to the top of the well point to serve as the casing of the completed well.

Drilling Machinery: A tripod, crab winch, bailers or sand pumps, cutter shoes, sinking pipe loading system, chain wrenches, pulley blocks, flexible steel wire rope, and tools such as spanners and wrenches are included in the equipment.

(II) Deep Tube Well Construction Methods

To select a drilling method for the construction of a deep tubewell, the following criteria should be considered by the employer and developer before construction work begins. Generally, tubewell of 4-24 inch size with various depth wells are constructed using fallowing methods in variety of groundwater aquifers.

Table 16.3 Performance of Drilling Methods for Type of Formation

Type of Formation	Cable and Tool	Mud Rotary	DTH
Dune sand	Difficult	Rapid	Not recommended
Loose sand and gravel	Difficult	Rapid	Not recommended
Quicksand	Difficult, except in thin streaks. Requires a string of drive pipe.	Rapid	Not recommended
Loose boulders in alluvial fans or glacial drift	Difficult – slow but Generally can be handled by driving pipe.	Difficult, Frequently impossible	Not recommended
Clay and silt	Slow	Rapid	Not recommended
Firm shale	Rapid	Rapid	Not recommended
Sticky shale	Slow	Rapid	Not recommended
Brittle shale	Rapid	Rapid	Not recommended
Sandstone – poorly cemented	Rapid	Rapid	Not recommended
Sandstone – well cemented	Fair	Slow	Not recommended
Chert nodules	Slow	Slow	Not recommended
Limestone	Slow	Rapid	Very Rapid
Limestone with chert nodules	Very Slow	Slow	Very Rapid
Limestone with small cracks or fractures	Very Slow	Slow	Very Rapid
Limestone cavernous	Very Slow	Slow to impossible	Difficult
Dolomite	Very Slow	Rapid	Very Rapid
Basalts, thin layers in sedimentary rocks	Slow	Slow	Very Rapid
Basalts – thick layers	Slow	Slow	Rapid
Metamorphic rocks	Slow	Slow	Rapid
Granite	Slow	Slow	Rapid

Source: Drillers Training and Reference Manual

Table 16.4: Classification of Drilling Rig

Classification of Drilling Rigs

Type of Drilling Rig	Classification	Limiting Diameter of Hole (mm)	Depth of Hole (m)	Size of Drill Rods (mm)
Percussion (cable tool)	Light	130	<50	–
	Medium	200	50–170	–
	Heavy	200	>170	–
Direct rotary	Light	200	0–250	73
	Medium	200	251–457	73–89
	Heavy	200	>457	89
Reverse rotary	Light	500	<170	150
	Medium	675	>170	150
Combination (rotary-cum-percussion)	Light		–	–
	Medium	200	<500	89
	Heavy	300	>500	89
Down-the-hole (DTH) hammer	Light	114	<50	89
	Medium	150	50–170	114
	Heavy	200	>170	114

Source: Das (1983).

a. Cable Tool Percussion Drilling

Cable tool drilling refers to mechanical percussion methods of drilling tube wells. Drilling is done in the same way as hand boring is done: by moving the tools up and down. The hard formations are broken or crushed into little bits by the drill bit. The drill bit loosens the material when operating in soft, unconsolidated rocks. The reciprocating movement of the instruments in both circumstances creates a slurry or sludge by mixing the crushed or loosened particles with water. If no water is available in the strata being penetrated, the appropriate water is introduced to the borehole to generate the slurry. A sand pump or bailer is used to drain the resultant slurry from the borehole at regular intervals. Sludge builds up on the tools, slowing their movement and, as a result, their penetration. The frequency with which the sludge is pumped from the well is usually determined by this component.

b. Rotary Drilling

Rotary drilling is accomplished by initiating rotation and applying axial pressure on the drill string and bit, while simultaneously initiating and maintaining circulation of a drilling fluid. The drilling fluid used might be made up of either water mixed with certain additives (see Guide D 5783) or pressurized air (see Guide D 5782) as the drilling fluid medium. The drilling fluid is circulated down through the inside of the drill string, out through the drill bit, and back up the annulus formed between the drill string and borehole wall, forward- or direct-rotary drilling method. Cuttings from the drilling operation are carried to the ground surface by the drilling fluid. At the ground surface, the cuttings-laden drilling fluid is discharged into a pit or series of pits where the drill cuttings settle out of the drilling fluid.

Direct-rotary drilling with Water-Based Drilling Fluid

Direct-rotary drilling and sampling, using various types of soil/rock sampling core barrels and devices, can be done in most soils and rocks. Direct-rotary drilling with water-based drilling fluid (ASTM Guide D 5783) is accomplished by initiating rotation and applying axial pressure on the drill string and bit while simultaneously initiating and maintaining the circulation of a drilling fluid. The drilling fluid is circulated down through the drill string and the cuttings-laden return comes back up the annulus formed between the drill string and the borehole wall. Cuttings from the drilling operation are carried to the ground surface by the circulating drilling

fluid. At the ground surface, the cuttings-laden drilling fluid is discharged into a pit or series of pits where the drill cuttings settle out of the drilling fluid.

Reverse-Circulation Drilling Using a Water-Based Drilling Fluid

Reverse-circulation drilling using a water-based drilling fluid is accomplished by applying a simultaneous combination of rotary and axial forces to the bit while initiating drilling fluid circulation through the system. In the reverse rotary drilling method, the drilling fluid is circulated down the annulus formed between the drill string and borehole wall, through the drill bit, and back up the inside of the drill string. Cuttings from the drilling operation are carried up the inside of the drill string by the drilling fluid. The cuttings-laden drilling fluid, subsequently, is discharged at the ground surface into a settling pit or series of settling pits where the drill cuttings settle out.

Clearwater, rather than mud, often is used as the drilling fluid. Commercially available drilling-fluid additives only are used to increase fluid density and viscosity to the point sufficient to carry cuttings to the surface; therefore, a drilling fluid control program is of much less concern in reverse circulation drilling than it is in fluid-rotary drilling. When the reverse-circulation drilling method is used, the user should be aware that the water used as a circulation medium can invade the aquifer, thereby, changing the native fluid chemistry of the aquifer. This occurrence should be documented. When drilling fluid additives are used in reverse rotary drilling, the same possible problems with regard to drilling-fluid effects on the ground-water chemistry apply to fluid-rotary drilling.

DTH Hammer and Air Rotary Drills

Due to the sluggish penetration rate, high bit cost, and high machinery maintenance cost, percussion and rotary well drilling methods are frequently uneconomical in water well drilling in hard rock locations. For drilling water wells in hard rock locations, air-operated DTH drills and air rotary drills have proven to be the most effective. Drilling with DTH machines blends percussion drilling's percussive action with rotary drilling's rotational motion. A pneumatic hammer is attached to the end of a drill string to create the tool. The hammer tool is made up of an air-operated piston that strikes the bit at a high frequency while being hydraulically forced into the rock. A hammering force is transmitted to the complete surface of the bottom of the hole by spinning the drill string at the same time, pulverizing the formation. The air entered for the hammering action is allowed to escape through the annular space between the hole and the drill string at the bottom of the hole, lifting the cuttings to the surface. Because the hammer at the bottom of the hole allows the piston to deliver the blows directly to the bit without losing energy through the drill string, DTH drilling provides for faster penetration. The hammer can drill granite up to three times faster than an air rotary drill and several times faster than percussion drilling. The bit's operation is influenced by the air compressor's capacity, the hammer's design, the bit's kind, and the type of coolant used throughout the drilling process. An air compressor supplies the necessary amount of air to run the hammer and clean the cuttings on a constant basis. Short, fast blows ensure a straight hole by reducing the effect of chipping and fracturing the formation. DTH drilling, on the other hand, is limited to small-diameter wells. The most common drill bit size is 7.5/8 inch. When rock-roller bits are utilized, however, the well size can be bigger (approximately 17.1/2 inches). Drilling in rocks with significant air pockets and deep water columns presents challenges. Air velocity in the annular space should be maintained between 600 and 1,500 m/min to properly remove the cuttings. A velocity of roughly 900 m/ min in the annular space is usually recommended. In some formations, excessive air velocities can produce hole enlargements. Surface equipment with relatively low back pressures can greatly reduce the annular air velocity near the surface.

Drilling Equipment Design:

A portable rig installed on a truck chassis or on a trailer is conventional equipment for drilling. The basic components of a percussion (1), rotatory(2), reverse rotatory(3), DTH (4), rig are (i) a mast (derrick)(1,2,3,4), (ii) a two- or three-line hoist, (1,2,3,4), (iii) a spudger for raising and lowering the tools (1,2,3), (iv) a diesel engine to power the numerous activities ((1,2,3,4), One line (the drilling reel) is used to operate drilling instruments, the second (the sand reel) is used to operate the bailer/sand pump, and the third (the casing reel) is used to operate boring pipes in a three-line hoist. (v) Mud Pump (2,3) and (vi) Air Compressor (2,3,4) The

mast is designed long enough to hoist the longest string of tools/pipes out of the pit, with a minimum height of roughly 10 m. During transit, the mast is telescoped to its shortest length and folded at the machine's top. The reels must be large enough to store enough cables for the deepest holes to be drilled. The rig can drill and is sturdy enough to handle the drilling and fishing tools, as well as other gear. The drilling process consists of three steps for percussion (1), rotatory (2), and reverse rotatory(3) methods: drilling the hole, bailing out the drilled cuttings (1), and lowering the casing pipes and screens in the bored hole. These three procedures are usually carried out one after the other until the bore is completed (Garden, 1958). The DTH method (4) employs the Air Rotatory method with casing and screen advancement method for the construction of a borehole.

Table 16.5: Minimum Specification of the Rig Machine for the construction of Deep Tube well

Drilling Machine	Reverse Rotary	Direct Rotary	Percussion	DTH
Minimum Drilling Capacity (m)	up to 350	up to 350	up to 250	up to 450
Compatible Drill Bits	Drag Bits, Tricone Bits, S	Drag Bits, Tricone Bits and Carbide Button	Chisel Bit	DTH Hammer or Button Bit
Drill Bits Size in inches	7.5/8 - 24	7.5/8 - 24	up to 24	up to 24
Individual Drill Rod Length (m)	3 to 6	3 to 6	-	3 to 6
Additional Equipment's	Air Compressor, Mast, Chain Pully, Wire lines, Mud Pump, Solid/Hollow Drill Rods	Air Compressor, Mast, Chain Pully, Wire lines, Mud Pump, Solid/Hollow Drill Rods	Mast, Cable Tool, Chain Pully, Wire lines	Air Compressor, Mast, Chain Pully, Wire lines, Mud Pump, Solid/Hollow Drill Rods

Deep Tube well Construction Process:

a. Site Preparation

- The Appropriate method of deep tube well construction should be established using Table 1- Table 5, before initiation of drilling equipment mobilization process to ensure best drilling method.
- The drilling equipment must be in good condition and appropriate for the terrain, expected site ground conditions and soils and rock anticipated. The equipment must include ancillary equipment suitable for cement grout mixing and injection.
- The drilling equipment must be clean and free from contaminants that would otherwise be introduced into the aquifer. All equipment should be cleaned by means of high-pressure hoses and/or steam, as appropriate. Where equipment has been used in circumstances where it may have been contaminated, e.g. by lying on ground recently occupied by livestock, it should be disinfected using appropriate disinfectants approved by SIH or Employer.
- Drilling fluids must be free of harmful chemicals. As far as practicable, drilling fluids should be limited to clean water, air, and approved foaming agents.
- Water used for mixing drilling fluid must be clean (of potable quality).
- Returned drilling fluid which is not re-circulated must be disposed of in a satisfactory manner, i.e. using (a) a sediment trap, and (b) a soak pit/Mud pit.
- A water well should be (a) straight, and (b) vertical: permanent well casing should not deviate more than 2º from the vertical. Straightness should be demonstrated by lowering down the hole a 6-meter.

- Fuel should not be stored on the site nor within vicinity of the well. If repairs or re-fueling on site are necessary, every care must be taken to ensure that no leakages or spillages occur. A drip tray should be used, and absorbent material should be available for mopping up any spillages quickly. If a large leakage of fuel or hydraulic fluid from the drilling equipment occurs, the contaminated ground must be rapidly excavated and removed off site for appropriate treatment and disposal.

Mud Pit: is a reservoir for the drilling fluid and, if properly designed and utilized, provides sufficient flow velocity reduction to allow separation of drill cuttings from the fluid before recirculation. The mud pit is usually a shallow, open metal tank with baffles; however, for some circumstances, an excavated pit with some type of liner, designed to prevent loss of drilling fluid and to contain potential contaminants that may be present in the cuttings and recirculated fluids may be used. The mud pit can be used as a mixing reservoir for the initial quantity of drilling fluid and, in some circumstances, for adding water and additives to the drilling fluid as drilling progresses.

Surface casing/Guide Pipe: is installed from ground surface through upper strata of unstable or fractured materials into a stable and, if possible, relatively impermeable material. Such surface casing serves several purposes, including: (1) supporting unstable materials during drilling, (2) reducing loss of drilling fluids, (3) facilitating installation or removal of other casing, (4) aiding in placing a sanitary seal, and (5) serving as a reservoir for a gravel pack. This casing may be temporary during drilling or it may be permanent.

Assembling centralizing and sinking of Guide pipe

Centralizing guides are affixed to the well assembly from the surface, ensuring its centering in the borehole and strengthening the stability of the surface wall. They facilitate uniform gravel pack thickness during gravel packing. Prior to drilling, it is imperative to cement the guide pipe securely to prevent any potential shifting and fall and caving at the mouth of bore.

General Specification: The diameter of the guide pipe should be greater than the final reaming size of the well (22-32-inch dia) depending upon the maximum size of bit used for construction of borehole and reaming. Minimum Length and Thickness and should be no less than 6 meter/12 mm.

Pilot Hole Drilling: The Pilot hole drilling is generally furnished by the 7-5/8 inch to 9-7/8-inch appropriate drill bit (Table 5) up to the depth demarcated in agreement by employer. As the drilling progresses the sample should be collected at appropriate interval by the site hydrogeologist. The logging of tube well drilling starts with the initiation of drilling process. The total depth of pilot hole during cost estimation/assumption by the experienced hydrogeologist yields expected required thickness of water bearing aquifer to provide design discharge, however, In the following unexpected cases total depth of borehole can be variated.

General condition of borehole depth variation:

1. Depth Reduction: Upon conformation of availability of total targeted formation thickness to obtain design discharge, proven by hydrogeological logs. Lowers cost of the project.

2. Depth Increment: To obtain the required thickness of formation to obtain design discharge proven by hydrogeological logs results in the significant Increase cost of the project.

General Specification for drill bit:

3. Bit should be compatible with the both geological formation and machine used for the formation (Table 5).

4. Drilling machine and Bit should be able to penetrate the ground with enough rate to facilitate the reaming of the bore hole.

5. Bit should be clear and hollow enough to allow drilling fluids to be circulated through the machinery and borehole to clear drill cuttings, cool the bit, and stabilize the borehole wall.

General Specification for Drilling fluid: Drilling Fluid, usually consists of a water base and one or more additives that increase viscosity or provide other desirable physical or chemical properties. Principal functions

of drilling fluid include: (1) sealing the borehole wall to minimize loss of drilling fluid, (2) providing a hydraulic pressure against the borehole wall to support the open borehole, (3) removing cuttings generated at the bit and (4) lubricating and cooling of the bit (ASTM D 5783).

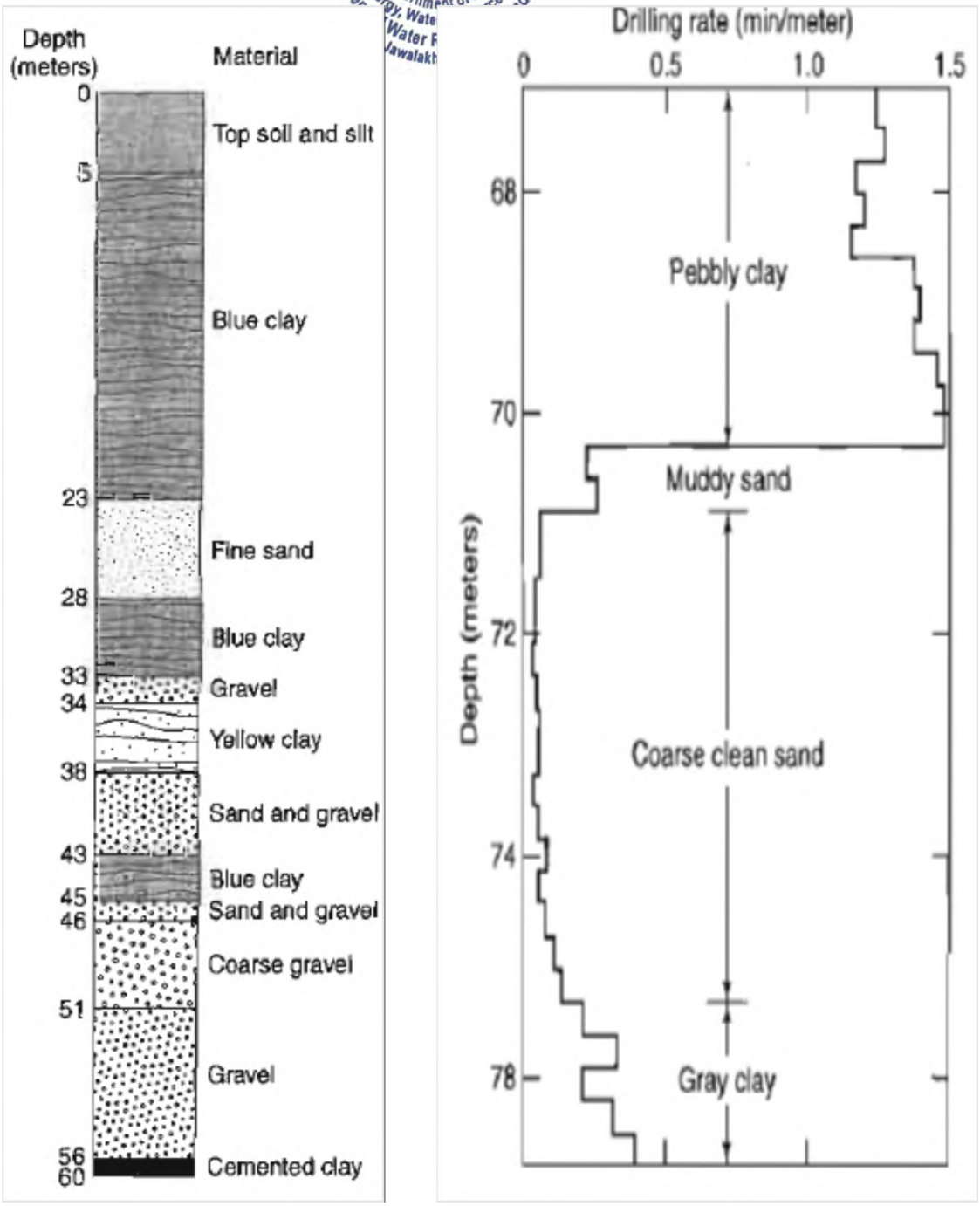
Sample collection

Undisturbed samples generally are not required for groundwater investigations. However, representative samples which preserve grain size and gradation relationships of granular materials are often required, especially for design criteria. So far as possible, the drilling method and equipment should be capable of yielding the necessary samples. Geologic log is constructed from sampling and examination of well cuttings collected at fre-quent intervals during the drilling of a well or test hole. Such logs furnish a description of the geologic character and thickness of each stratum encountered as a function of depth, thereby enabling aquifers to be delineated.

1606 BOREHOLE LOGGING

There are various types of bore hole logging methods that could be deployed in a well to conform exact aquifer positioning correlation with nearby well logs, and placement of screen. The methods are listed below.

Geological Logs: Considering all types of logs, the geologic log is probably the most important, but preparation of a good geologic log can be difficult. One problem is that well cuttings are small and mixed with mud. Particularly in rotary drilling, the drilling mud masks the presence of material in the silt and clay ranges. Another problem stems from the fact that most geologic logs are prepared by well drillers, who are busy with many activities during drilling operations and sometimes lack formal geologic training;



Therefore, logs often tend to be prepared in a per-functory manner by site hydrogeologist (SIH). But experienced drillers, who recognize the value of geologic logs, make diligent efforts to prepare them carefully and completely.

It is good practice to store samples of well cuttings systematically in intervals of 0.5 m to 3 m with 0.5/1.0 kg basis but good lithological logs result yields at the 0.5-1.0 m interval sampling. These not only permit detailed geologic logs to be prepared but also enable grain size analyses and correlations with other nearby wells to be made after drilling is finished. A good geological logs shows well cuttings collected by a bucket sampler during drilling; they have been arranged in order on the ground, bagged, and labeled for storage and for sieve analysis. (Figure)

Figure: Prepared Geological Log (Left) from sample and Drilling time log and strata penetration (after Kirby)

Drilling-Time Log: A drilling-time log is a useful supplement to borehole drilling. It consists of an accurate

record of the time, in minutes and seconds, required to drill each unit depth of the hole. The technique is most practical with hydraulic rotary drilling although it is applicable to other methods as well. Because the texture of a stratum being penetrated largely governs the drilling rate, a drilling-time log may be readily interpreted in terms of formation types and depths. A portion of a drilling time log obtained by the hydraulic rotary method is shown in Figure together with the log of the test hole based on cuttings. The interpretation of formation condition can be done in terms of material hardness and viscosity, penetration rate, depth and other parameters.

Machineries: Timer (High Precision)

Interval of Logging: 0.5, 1 meter as specified by employer, SIH, HG

Caliper Log: The Caliper Log is a tool for measuring the diameter, geometry and shape of a borehole. It uses a tool which has 2, 4, or more extendable arms. The arms can move in and out as the tool is withdrawn from the borehole, and the movement is converted into an electrical signal by a potentiometer. This is shown in track 1 of the master log together with the bit size for reference. Borehole diameters larger and smaller than the bit size are possible. Modern caliper logging tools are equipped with the Borehole Geometry Tool (BGT), which provides the information of bore hole geometry and deviation of formation from the bit size. The interpretation of formation condition can be done in terms of local hydrostatic pressure, materials and other parameters as shown in table 16.6.

Table 16.6: Caliper logging result and interpreted formations

Hole Diameter	Cause	Possible Lithologies/Condition
On Gauge	Hard formations Well consolidated formations Non-permeable formations.	Gravel beds Massive rocks Clay
Larger than Bit Size	Water/drill mud soluble formations High-Permeable formations.	Clay, Silt, Sand High hydrostatic pressure on water bearing sedimentary formation
Smaller than Bit Size	Formations swell and flow into borehole. Development of mud cake for porous and permeable formations.	Swelling clay materials Porous, permeable rocks.

Machineries caliper logging machine with Borehole Geometry Tool (BGT) recording depth and temperature features.

Interval of Logging: In general: 0.5 - 1 meter, as capacity of logger or as specified by employer, SIH, HG

Temperature Logging: A vertical traverse measurement of groundwater temperature in a well can be readily obtained with a recording resistance thermometer. Such data can be of value in analyzing subsurface conditions. Ordinarily, temperatures will increase with depth in accordance with the geothermal gradient, amounting to roughly 3 C for each 100 min depth. Departures from this normal gradient may provide information on circulation or geologic conditions in the well. Abnormally cold temperatures may indicate the presence of gas or, in deep wells, may suggest recharge from ground surface. Likewise, abnormally warm water may occur from water of deep-seated origin. Temperatures may indicate waters from different aquifers intersected by a well. In a few instances, temperature logs have aided the location of the approximate top of new concrete behind a casing because the heat generated during setting produces a marked temperature increase of the water within the casing.

Machineries Sensitive Thermometer with recording depth and temperature features.

Interval of Logging: In general: 0.5 - 1 meter, as capacity of logger or as specified by employer, SIH, HG

GEOPHYSICAL LOGGING: Geophysical logging involves lowering sensing devices in a borehole and recording a physical parameter that may be interpreted in terms of formation characteristics; groundwater quantity, quality, and movement; or physic al structure of the borehole. A wide variety of logging techniques are available; Table 16.7 lists the types of information that can be obtained from various logging techniques, among them only resistivity and gamma-gamma logging is described in detail.

Table 16.7: Summery of Logging Applications to Groundwater Hydrology (after Keys and MacCrary)

Required information	Possible logging techniques
Lithology and stratigraphic correlation of aquifers and associated rocks	Resistivity, sonic, or caliper logs made in open holes; radiation logs made in open or cased holes
Total porosity or bulk density	Calibrated sonic logs in open holes; calibrated neutron or gamma-gamma logs in open or cased holes
Effective porosity or true resistivity	Calibrated long-normal resistivity logs
Clay or shale content	Natural gamma logs
Permeability	Under some conditions, long-normal resistivity logs
Secondary permeability—fractures, solution openings	Caliper, sonic, or television logs
Specific yield of unconfined aquifers	Calibrated neutron logs
Grain size	Possible relation to formation factor derived from resistivity logs
Location of water level or saturated zones	Resistivity, temperature, or fluid conductivity logs; neutron or gamma-gamma logs in open or cased holes
Moisture content	Calibrated neutron logs
Infiltration	Time-interval neutron logs
Dispersion, dilution, and movement of waste	Fluid conductivity or temperature logs; natural gamma logs for some radioactive wastes
Source and movement of water in a well	Fluid velocity or temperature logs
Chemical and physical characteristics of water, including salinity, temperature, density and viscosity	Calibrated fluid conductivity or temperature logs; resistivity logs
Construction of existing wells, diameter and position of casing, perforations, screens	Gamma-gamma, caliper, casing, or television logs
Guide to screen setting	All logs providing data on the lithology, water-bearing characteristics, and correlation and thickness of aquifers
Cementing	Caliper, temperature, or gamma-gamma logs; acoustic logs for cement bond
Casing corrosion	Under some conditions, caliper, casing, or television logs
Casing leaks and/or plugged screen	Fluid velocity logs

Resistivity Logging:

Within an uncased well, current and potential electrodes can be lowered to measure electric resistivities of the surrounding media and to obtain a trace of their variation with depth. The result is a resistivity (or electric) log. Such a log is affected by fluid within a well, by well diameter, by the character of surrounding strata, and by groundwater. Of several possible methods for measuring underground resistivities, the multielectrode method is most commonly employed, because it minimizes effects of the drilling fluid and well diameter and also makes possible a direct comparison of several recorded resistivity curves. Four electrodes, two for emitting current and two for potential measurement, constitute the system. Recorded curves are termed Short normal from data from shorter electrode, Long normal for data from longer electrodes and Self-Potential values. Which are plotted in the logarithmic graph in software such as Log plot or Excel sheet and interpreted as according to the values of data shown in the Table and correlated with the geological, other types of logs as well as obtained resistivity values can be used to calculate the approximate porosity and permeability of aquifer materials

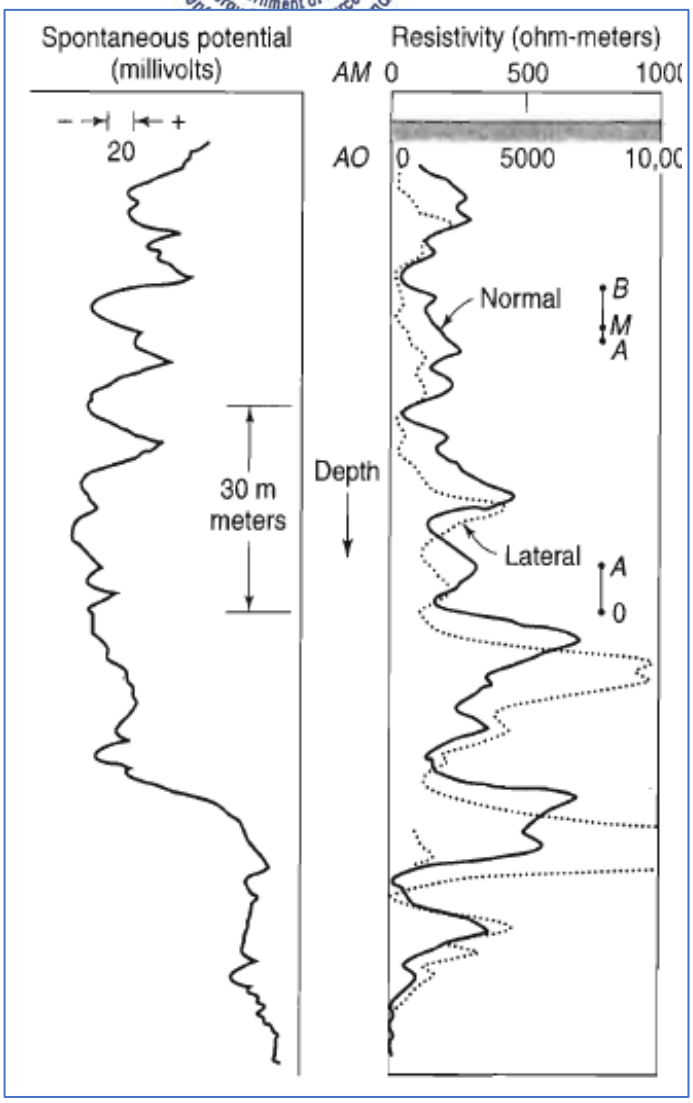


Figure 16.3: SN, LN, SP Plot (after Schlumberger Well Surveying Corp)

Table 16.8: Resistivity value of various materials observed in Nepal.

Resistivity (Ohm-m)	**Geological Material**
+1000	Hard bedrock
<1000	Fractured bedrock
+4,000	Boulder, cobble, pebble (above WL)
+2,000	Boulder, cobble, pebble (Below WL)
250- 1000	Gravel, coarse sand
100 - 250	Fine to Coarse Sand
50 – 100	Silt, Fine Sand
<50	Clay, Silt

SP Log: The spontaneous potential method measures natural electrical potentials found within the earth. Measurements, usually in millivolts, are obtained from a recording potentiometer connected to two like electrodes. One electrode is lowered in an uncased well and the other is connected to the ground surface.

The potentials are primarily produced by electrochemical cells fanned by the electrical conductivity differences of drilling mud and groundwater where boundaries of permeable zones intersect a borehole. In some instances, electro kinetic effects of fluids moving through permeable formations are also responsible for spontaneous potentials. Therefore, potential logs indicate permeable zones but not in absolute terms; they can also aid in determining casing lengths and in estimating total dissolved solids in groundwater.

Machineries: Resistivity Logger Machine capable of measuring of SP values with Accessories

Interval of Logging: 0.5, 1 meter as specified by employer, SIH, HG

General Specifications: Machine should record resistivity (LN, SN) and SP data at the certain intervals up to required depth with precision. 2. Can be tested and calibrated at the field. 3. Should be user friendly.

RADIATION LOGGING

Radiation logging, also known as nuclear or radioactive logging, involves the measurement of fundamental particles emitted from unstable radioactive isotopes. Logs having application to groundwater are natural gamma, gamma-gamma, and neutron. These are promising but not widely used hydro geologic tools. An important advantage of these logs over most others is that they may be recorded in either cased or open holes that are filled with any fluid.

Natural-Gamma Logging: Because all rocks emit natural-gamma radiation, a record of this constitutes a natural-gamma log. The radiation originates from unstable isotopes of potassium, uranium, and thorium. In general, the natural-gamma activity of clayey formations is significantly higher than that of quartz sands and carbonate rocks. The most important application to groundwater hydrology is identification of lithology, particularly clayey or shale-bearing sediments, which possess the highest gamma intensity. Because most of the gamma rays detected originate within 15-30 cm of the borehole wall, logs run before and after well development can reveal zones where clay and fine-grained material were removed. Borehole dimensions and fluid, casing, and gravel pack all exert minor influences on gamma probe measurements. Well Design, Screens selection and Gravel Packs.

Gamma-Gamma Logging: Gamma radiation originating from a source probe and recorded after it is backscattered and attenuated within the borehole and surrounding formation constitutes a gamma-gamma log. The source probe generally contains cobalt-60 or cesium-137, which is shielded from a sodium iodide detector built into the probe. Primary applications of gamma-gamma logs are for identification of lithology and measurement of bulk density and porosity of rocks within the same geologic formation it should be possible to derive specific yield from the difference in bulk density measured above and below a water table. Finally, gamma-gamma logs can assist in locating casing, collars, grout, and zones of hole enlargement. As with natural-gamma logs, borehole and fluid conditions affect readings.

Machineries Gamma Ray Logger Machine with Accessories

Interval of Logging: 0.5, 1 meter as specified by employer, SIH, HG

General Specifications: Machine should record resistivity minimum Potassium, Uranium, Thorium & Total Gamma (KeV) count data at the certain intervals up to required depth with precision. 2. Can be tested and calibrated at the field. 3. Should be user friendly and portable.

Well Design: After completion of various type of logging in the bore hole, a master log is prepared alongside with the geological log. Anomalies were removed and final log is prepared and often correlated with the nearby well logs and surface geophysical logs to determine formation boundaries and thickness of aquifer. The final well design conforms the total depth of tub well, screen positions, secondary housing depth, gravel packing scheme, sealing materials and depth and other necessary information's.

For well design it is necessary to consider the following points:

1. Minimum entrance velocity,

2. Maximum open area of screen,

3. Correct design of slot to minimize blockage,

4. Selection of screen slot to fit aquifer or gravel pack material,

5. Periodic maintenance,

6. Selection of screen material for corrosion resistance,

1607 DETERMINATION OF SCREEN POSITIONS:

Determination of Secondarily Housing

- **First Reaming**

The first reaming is generally furnished for the enlargement of borehole and smoothing out the borehole wall to accommodate the screen and housing and gravel pack up to additional 6 meter in hard formation and 18 meter in soft formation then total lowering depth determined in well design to minimize the risk of fill up of bore hole by accidental conditions. The borehole should be first reamed by the bit of size greater than 9.7/8 inch to 13-3/4-inch for hard formation, borehole located in the medium formation should be reamed by the drll bit size upto 17.1/2 inch and whereas, for the fine sedimentary soft formation drill bit should be used up to 22-inch appropriate drill bit (Table 5) to ream the hole for adequate annular space for the artificial gravel packing.

General Specification for drill bit:

1. Bit should be compatible with the both geological formation and machine used for the formation (Table 5).

2. Drilling machine and Bit should be able to penetrate the ground with enough rate to facilitate the reaming of the bore hole.

3. Bit should be clear and hollow enough to allow drilling fluids to be circulated through the machinery and borehole to clear drill cuttings, cool the bit, and stabilize the borehole wall.

- **Second Reaming**

The second reaming is generally furnished for the pump housing by the bit of size greater than 17-1/2-inch for hard formation more than the dynamic water level plus seasonal fluctuations and other factors (See Secondarily Housing) to ensure optimal discharge from the pump, borehole located in the medium formation should be reamed by the bit size upto 22 inch and whereas, for the fine sedimentary soft formation drill bit should be used up to 32 inch appropriate drill bit (Table 5) to ream the hole for adequate annular space for the artificial gravel packing.

General Specification for drill bit:

1. Bit should be compatible with the both geological formation and machine used for the formation (Table 5).

2. Drilling machine and Bit should be able to penetrate the ground with enough rate to facilitate the reaming of the bore hole.

3. Bit should be clear and hollow enough to allow drilling fluids to be circulated through the machinery and borehole to clear drill cuttings, cool the bit, and stabilize the borehole wall.

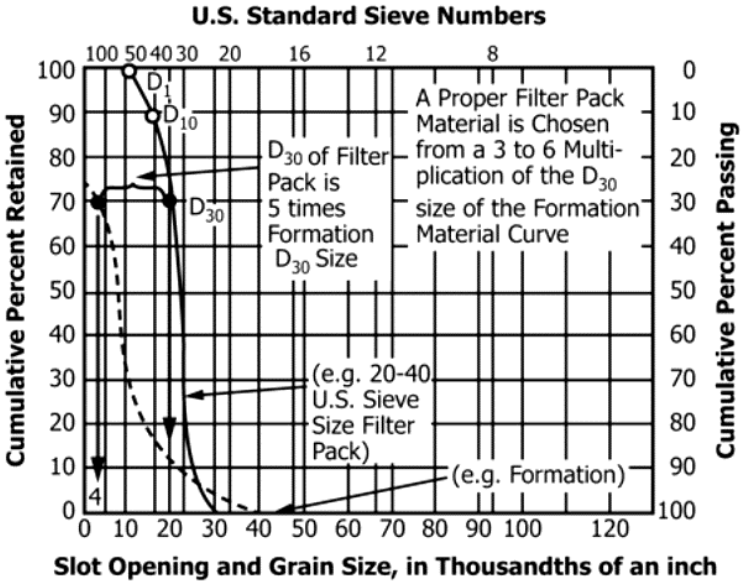
Gravel/Filter Pack Selection:

A gravel-packed well is one containing an artificially placed gravel screen or envelope surrounding the well screen. A gravel pack (l) stabilizes the aquifer, (2) minimizes sand pumping, (3) permits use of a large screen

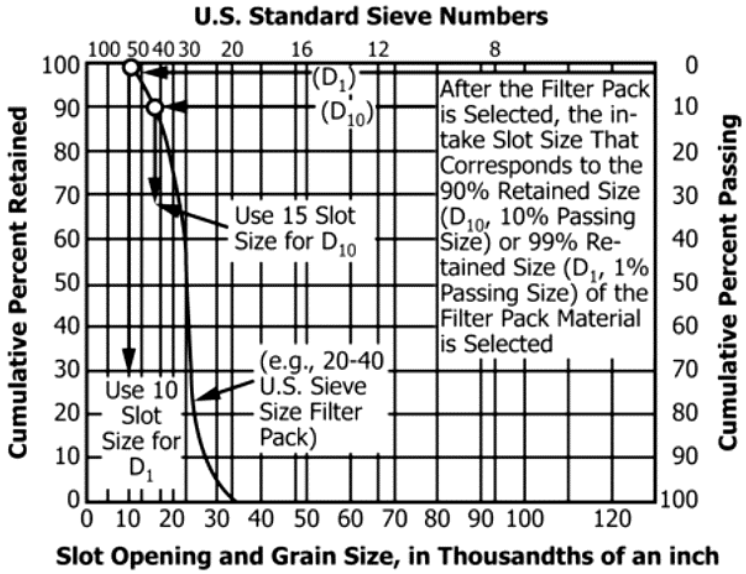
slot with a maximum open area. Natural gravel pack is omitted in this section.

Coarse Grained Formations- For formation materials that are relatively coarse-grained (that is, fine, medium and coarse sands and gravels), the grain size distribution of the primary filter pack is determined by calculating the D30 (30 % finer) size, the D60 (60 % finer) size, and the D10 (10 % finer) size of the filter pack. The first point on the filter pack grain-size distribution curve is the D30 size. The primary filter pack is usually selected to have a D30 grain size that is about 4 to 6 times greater than the D30 grain size of the formation material being retained (see Figure). A multiplication factor of 4 is used if the formation material is relatively fine-grained and well sorted or uniform (small range in grain sizes); a multiplication factor of 6 is used if the formation is relatively coarse grained and poorly sorted or non-uniform (large range in grain sizes). Thus, 70 % of the filter pack will have a grain size that is 4 to 6 times larger than the D30 size of the formation materials. This ensures that the filter pack is coarser (with a higher hydraulic conductivity) than the formation material, and allows for unrestricted groundwater flow from the formation into the discharge well. The next 2 points on the filter pack grain-size distribution curve are the D60 and D10 grain sizes. These are chosen so that the ratio between the two grain sizes (the uniformity coefficient) is less than 2.5. This ensures that the filter pack has a small range in grain sizes and is uniform as possible. The D60 and D10 grain sizes of the filter pack are calculated by a trial and error method using grain sizes that are close to the D30 size of the filter pack. After the D30, D60 and D10 sizes of the filter pack are determined, a smooth curve is drawn through these points. The final step in filter pack design is to specify the limits of the grain size envelope, which defines the permissible range in grain sizes for the filter pack. The permissible range on either side of the grain size curve is 8 %. The boundaries of the grain size envelope are drawn on either side of the filter pack grain-size distribution curve, and filter pack design is complete. (ASTM D5092).

Fine-Grained Formations—In formation materials that are predominantly fine-grained (finer than fine to very fine sands), soil piping can occur when a hydraulic gradient exists between the formation and the well (as would be the case during well development and sampling). To prevent soil piping in these materials, the following criteria are used for designing granular filter packs: D15 of filter D85 of formation # 4 to 5 and D15 of filter D15 of formation $4 to 5. The left half of this equation is the fundamental criterion for the prevention of soil piping through a granular filter, while the right half of the equation is the hydraulic conductivity criterion. This latter criterion serves the same purpose as multiplying the D30 grain size of the formation by a factor of between 4 and 6 for coarser formation materials. Filter pack materials suitable for retaining formation materials in formations that are predominantly fine-grained are themselves, by necessity, relatively fine-grained (for example, fine to very fine sands), presenting several problems for well designers and installers. First, well screen slot sizes suitable for retaining such fine-grained filter pack materials are not widely available (the smallest commercially available slotted well casing is 6 slot, 0.006 in. [0.15 mm]; the smallest commercially available continuous-slot wire-wound screen is 4 slot, 0.004 in. [0.10 mm]). Second, the finest filter pack material practical for conventional (tremie tube) installation is a #40 by #70 sieve size, [425 to 212 µm] sand, which can be used with a well screen slot as small as 8 slot, 0.008-in., [0.20 mm]. Finer grained filter pack materials cannot be placed practically by either tremie tubes or pouring down the annular space or down augers. (ASTM D5092).



The filter-pack material selected to surround the well screen should have a 70% retained size that is three to six times greater than the 70% retained size of the formation materials. In this example, a multiplier of 5 was selected, based on formation material characteristics.



The well screen slot size is selected to retain between 90 and 99% of the selected filter-pack material.

Fig.16.4 Example Grading Curves for Design of Filter Pack and Slot Size

Casing selection:

Well casing serves as a lining to maintain an open hole from ground surface to the aquifer. It seals out surface water and any undesirable groundwater and also provides structural support against caving materials outside the well. Materials commonly employed for well casings are wrought iron, alloyed or unalloyed steel, and ingot iron. Joints normally consist of threaded couplings or are welded with color or less preferably using strips, the object being to secure water tightness. In cable-tool drilling, the casing is driven into place; in rotary methods, the casing is smaller than the drilled hole and hence can be lowered into place. Polyvinyl chloride (PVC) pipe is widely employed as casing for shallow, small-diameter observation wells. Recommended minimum diameters of surface casing are given in Table and Table Above.

Table 16.9: Diameters for Well Casings and Screens (after U.S. Bureau of Reclamation)

Well yield (m^3/day)	Nominal pump chamber casing diameter (cm)	Surface Casing Diameter (cm)		Nominal screen diameter (cm)
		Naturally developed wells	Gravel-packed wells	
< 270	15	25	45	5
270–680	20	30	50	10
680–1,900	25	35	55	15
1,900–4,400	30	40	60	20
4,400–7,600	35	45	65	25
7,600–14,000	40	50	70	30
14,000–19,000	50	60	80	35
19,000–27,000	60	70	90	40

Table above: The selection of well screen and blind pipe materials and their resistance to acidic water and abrasive effect are summarized below.

Material	Acid Resistance	Corrosion resistance with normal groundwater	Remarks
PVC	Good	Good	Non-Corrosive and Incrustation
Mild Steel	Poor	Poor	Highly Corrosive and Incrustation
Galvanized Iron	Poor	Fair	Fairly Corrosive and Incrustation
Stainless Steel	Good	Very Good	Mild Corrosive and Incrustation

Screen Selection:

Screened wells typically are classified as either natural–packed (for DTH well) or artificially–packed wells (for Rotary, Reverse Rotary and Percussion well). In the natural–pack type, a screen–slot size is selected which will allow a definite proportion of the finer part of the aquifer adjacent to the screen to pass into the well for removal during development see Table. The remaining envelope of coarser aquifer material around the screen serves as a retainer for surrounding fine–grained deposits. In the artificial–pack type, an envelope of materials having a coarser uniform grain size than the aquifer is mechanically placed around the screen to serve as a filter for the finer formation particles. The design criteria for either type as described by Smith (1954) or Walton (1962), are based on the effective size, uniformity coefficient, and other grain-size distribution considerations determined from a mechanical analysis of the aquifer material and water quality Table above. A natural–pack well normally can be justified if the effective grain size of the aquifer is greater than o.o1 inch and the uniformity coefficient is above 3. An artificial pack usually proves to be desirable if either the effective size or uniformity coefficient is much below these values.

a. Open Area of Well Screen

The entrance velocity Va of the water into the well screen is used to determine the open area of screen Ar:

Va=Q/Ar; Where, Q=yield (m3/sec); Va=entrance velocity (m/sec); Ar= Open area (m2).

The entrance velocity should be kept to a minimum, and in general a velocity of o.1 m/sec with negligible friction loss and least encrustation corrosion. It is suggested that an open screen area more percent gives little increase in efficiency; however the performance decrease considerably when open area <15 percent (Stramel 1965). It is relative to note that the higher the percentage of open area available, the more area there is to be blocked and the head loss becomes significant, and therefore additional open area should result in an increase efficiency over a longer period of time.

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b. Determination of Slot size

Determination of screen slot size depends on critical particle size of aquifer or gravel pack be retained. A standard sieve analysis of the aquifer material or gravel pack material determines this slots. A considerable range of percentage of gravel pack to be retained by the screen is suggested in both the theoretical and technical literature (Johnson technical bulletins) . The usual rule is that at least 90 percent of the gravel pack should be retained where the pack and aquifer is uniform; however, values as low as 40 percent have been suggested if there is bad uniformity. The screen selection criteria used by the water survey are based upon optimum screen–entrance velocities considering aquifer permeability and screen area effectively open to the water–bearing material. For natural–packed wells, the proper screen length and/or optimum discharge rate are determined from the equation:

LS=Q/7.48 Ae Vc; Where: Ls=length of screen, in m; Q= optimum discharge, in lpm; Ae=effective open area per meter of screen, in sq m; **Vc =optimum entrance velocity, in mpm.**

Reconditioning of Borehole

Before lowering of Pipe assembly, bore hole shall be reconditioned to the satisfaction of the Engineer. Reconditioning of a borehole involves various processes aimed at restoring its functionality, improving water quality, or enhancing flow rates. In general, the noteable processes involved in reconditioning are Cleaning, Chemical Treatment, Grouting, Development, Testing and Monitoring.

Lowering of Pipe Assembly

Lowering a pipe assembly into a borehole is a critical step in drilling and well installation. After reconditioning of borehole, the lowering of pipe assembly of required diameter shall be made to the required depth as specified in BoQ or instructed by the Engineer. Before lowering the pipe assembly, the contractor should be assured that the pipe assembly including casing and screening is free from defects and borehole is thoroughly clear from debris or settlement to facilitate smooth lowering.

1608 WELL DEVELOPMENT

Following completion, a new well is developed to increase its specific capacity, prevent sanding, and obtain maximum economic well life. These results are accomplished by removing the finer material from the natural formations surrounding the perforated sections of the casing. Where a well has been gravel packed, much of the same purpose has been accomplished, although development is still beneficial. The importance of developing wells cannot be underestimated; all too often development is not carried out adequately to produce full potential yields. Development procedures are varied and include pumping, surging, use of compressed air, hydraulic jetting, addition of chemicals These are briefly described in subsequent paragraphs.

Inner Washing and Back Washing

Inner washing and backwashing are important techniques in well development to enhance water flow, remove obstructions, and improve water quality.

Inner Washing

Inner washing is designed to clean the interior of the well casing and screen, removing sediment, biofilms, and mineral deposits.

Process:

- **Water Injection**: High-pressure water is injected into the well through a specialized tool, such as a jetting tool or a submersible pump.
- **Agitation:** The water creates turbulence, dislodging particles and debris from the well walls and screen.
- **Circulation:** The dislodged materials are circulated back to the surface, often through the same pipe or a separate return line.

- **Repeat**: This process is repeated several times until the desired cleanliness is achieved.

Back Washing (with Air)

In the backwashing method, the top of the well is fitted with an airtight cover. Discharge and air pipes are installed similar to the previous method, together with a separate short air pipe and a three-way valve. Compressed air is released through the long air pipe, forcing air and water out of the well through the discharge pipe. After the water clears, the air supply is shut off and the water is allowed to return to its static level.

Hydraulic Jetting (with Water)

Jetting with a high-velocity stream of water is an effective development technique in open rock holes and in wells containing screens with large percentage openings (see Figure 5.5.3). The jet nozzle, mounted horizontally, is attached to a string of pipe, which is connected through a swivel and hose to a high-pressure, high-capacity pump. The jet head is slowly rotated to successively higher levels. Fine-grained material from unconsolidated aquifers is carried into the well by the turbulent flow; in addition, the method is particularly effective in developing gravel-packed wells.

By Compressor

Surging

This procedure involves pumping a well in a series of steps from a low discharge to one exceeding the design capacity. To be most effective, the intake area of the pump should extend to near the center of the screened section. At each step the well is pumped until the water clears, after which the power is shut off and water in the pump column surges back into the well. The step is repeated until only clear water appears. The discharge rate is then increased and the procedure repeated until the final rate is the maximum capacity of the pump or well. This irregular and non-continuous pumping agitates the fine material surrounding the well so that it can be carried into the well and pumped out. The coarser fraction entering the well is removed by a bailer or sand pump from the bottom. This development method by pumping is recommended as a finishing procedure after any of the development techniques described subsequently.

By Pump

This procedure involves pumping a well in a series of steps from a low discharge to one exceeding the design capacity.* To be most effective, the intake area of the pump should extend to near the center of the screened section. At each step the well is pumped until the water clears, after which the power is shut off and water in the pump column surges back into the well. The step is repeated until only clear water appears. The discharge rate is then increased and the procedure repeated until the final rate is the maximum capacity of the pump or well. This irregular and non-continuous pumping agitates the fine material surrounding the well so that it can be carried into the well and pumped out. The coarser fraction entering the well is removed by a bailer or sand pump from the bottom. This development method by pumping is recommended as a finishing procedure after any of the development techniques described subsequently.

Well Tests

Following development of a new well, it should be tested lo determine its yield and drawdown. This information provides a basis for determining the water supply available from the well, for selecting the type of pump, and for estimating the cost of pumping. A test is accomplished by measuring the static water level, after which the well is pumped at a maximum rate until the water level in the well stabilizes. The depth to water is then noted in the difference in depths is the drawdown, and the discharge--drawdown ratio is an estimate of the specific capacity of the well. The discharge can be determined by any of several measuring devices connected to the discharge pipe.

1609 PUMP INSTALLATION

Pump installation involves several important steps such as site selection, pump selection, assembling of pump component, lowering of pump, electric connections for power supply, etc to ensure efficient operation and

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longevity of the well-constructed.

Pump Selection

Based on the flow rate and total head (including static head and frictional loss) against which the pump has to operate, the capacity of pump required to draw water from the well is determined. The pump selected should be from the reliable and established manufacturing company. Since, the shallow tube well draws water from unconfined aquifer, its depth is generally low and hence jet pump or submersible pump are applicable. The contractor shall be responsible to use reliable pump of required capacity as mentioned in the BoQ or approved by the Engineer.

Since, the deep tube well generally draws water from confined aquifer, its depth is necessarily high and hence vertical turbine pump or submersible pump are applicable. The contractor shall be responsible to use reliable pump of required capacity as mentioned in the BoQ or approved by the Engineer.

Column Pipe Selection

Pump chamber casing/Column Pipe: comprises all casing above the screen in wells of uniform diameter. Colum pipe to be used shall be of required material and diameter as specified in BoQ of Contract Documents.

For telescoping wells, it is the casing within which the pump bowls are set. Recommended minimum diameters are listed in above Table. Normally, the Pump chamber casing should have a nominal diameter at least 5 cm larger than the nominal diameter of the pump bowls. Nonmetallic pipes are sometimes employed where corrosion or incrustation is a problem. Possibilities include ceramic-clay, concrete, asbestos-cement, plastic, and fiberglass-reinforced plastic pipe; strengths of these materials are not comparable to steel pipe, however.

Reaming of Pilot hole

Reaming shall be done upto the approved design depth. The reaming size specified on the basis of Table 10 below. Reaming can be done in two to three stages according to the size and formation of the area.

Annular space

The size of annular space between the hole and the Casing/Housing depends upon the grain size of Aquifer materials. The thickness of annular space in finer formation must be increased on the recommendation of expert. The annular space between the bore and the casing pipe for sand and gravel formation shall be as follows in Table 16.10.

Table 16.10: General requirement of Annular space between the bore and the casing pipe with respect to depth.

Type of Borewell	Depth of Borewell	Minimum Thickness of Annular Space	Minimum Diameter of bore hole
Borewells with filter pack (Percussion and Rotary Method	Less than 125m	3”	D+6”
	125 to 250m	4”	D+8”
	More than 250m	6”	D+12”
Naturally developed borewells without gravel pack (DTH method)	Less than 125m	1”	D+2”
	More than 125m	1½”	D+3”

Note: The annular space will be decided by the expert in the field.

Recondition of Reaming hole process

The hole should be clean up to the lowering depth. The Viscosity of the mud inside the well shall reduce to 50% of drilling fluid during drilling process by backwashing process

Lowering of pipe assembly process

The Pipes shall be arranged according to design by numbering in a row before lowering as per pipe arrangement plan mentioned in Appendix 2. The hole shall be clear up to the bottom contains no drill cutting to the lowering depth. Ring or plate shall be used to connect the MS pipe-MS Pipe or MS pipe and screen welded to its circumference. MS rod shall used for welding between MS pipes and steel rods shall be for welding in MS and SS/ LCG screen. The welding shall be done throughout its circumference without leaving any gap or hole between the pipes.

Tube wells must be perfectly vertical. A simple method is to use torpedo bubble level. Absolute verticality is ideal but a deviation of 10mm per 40 metres of tubewell is generally acceptable.

Centralizer is used to keep the casing centred in the borehole and away from the borehole wall to facilitate uniform gravel packing throughout the well. It also assists the for proper sealing of the well resulting protection against contamination. The spacing and number of centralizers shall be decided by site in charge. The typical design of the centraliser is shown in the Figure 16.7.

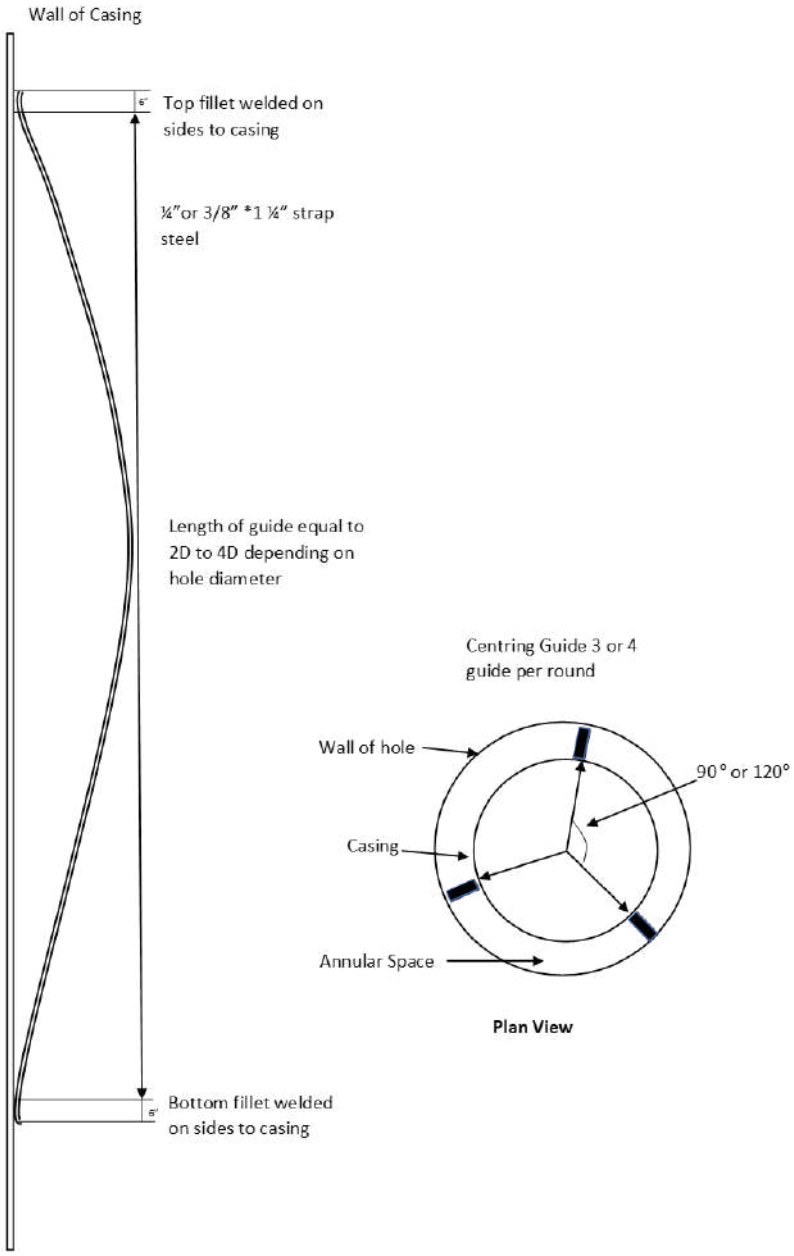

Figure 16.7: Typical Design of Centralizer

Guideline, Selection Criteria and Specifications of Method and Materials used in the Well Construction Terminology and Specifications of Construction Materials (Ref. DTW Norms).

- Soft Formation: Clay, Silt, and Sand below fine gravel (up to particle size 4.75 mm).
- Medium Formation: fine gravel to medium (from particle size 4.75 mm to 16 mm).
- Hard Formation: above coarse gravel (>16 mm), Rock strata).
- Digging and Lifting Tools: digging tools such as shovels or backhoes, pick axes, and transportation tools.
- Dewatering of dug well during construction: Locally available surface/submersible pump 5-7 hp.
- Concrete RCC Cement Ring: Size: 150 - 1200 mm (dia), Thickness: 40-80 mm, as available in the market.

Sealing gaps between RCC Rings: The gaps between RCC rings above the water-bearing formation/strata must be sealed using grout/cement or bentonite (less feasible) to avoid contamination.

Recondition of Borehole: Bentonite, Drill bit, and Barite,

Lowering Pipe Assembly: Lowering a pipe assembly into a dugwell is a critical step in drilling and well installation. After construction of dugwell, the lowering of pipe assembly of required diameter shall be made to the required depth as specified in BoQ or instructed by the Engineer. Before lowering the pipe assembly, the contractor should be assured that the pipe assembly including screening is free from defects and dugwell is thoroughly clear from debris or settlement to facilitate smooth lowering.

Well, Development by Drilling Rig (Back Washing and Inner Washing):

Effective development procedures should cause reversals of flow through the screen openings that will agitate the sediment, remove the finer fraction, and then rearrange the remaining formation particles. Reversing the direction of flow breaks down the bridging between large particles and across screen openings that results then the water flows in only one direction. The backflow portion of a backwashing cycle breaks down bridging, and the inflow then moves the fine material toward the screen and into the well. A surging action consists of alternately lifting a column of water a significant distance above the pumping water level and letting the water fall back into the well. this process is called rawhiding. Before beginning the surging operation, the pump should be started at reduced capacity and gradually increased to full capacity to minimize the danger of sand-locking the pump. In the rawhiding procedure, the pump is started, and as soon as water is lifted to the surface the pump is shut off; the water in the pump column pipe then falls back into the well. The pump is started and stopped as rapidly as the power unit and starting equipment will permit. To avoid damagjng the pump, the control box should be equipped with a starter lockout so that the pump cannot be started when it is back spinning. During the procedure, the well should be pumped to waste occasionally to remove the sand that has been brought in by the surging action. Some wells respond satisfactorily to rawhiding, but in many cases the surging effect is not vigorous enough to obtain maximum results. As in the case of over pumping, the surging effects may be concentrated only near the top of the screen or in the most permeable zones. Thus, the lower part of a long screen may remain relatively undeveloped. Although overpumping and backwashing techniques are used widely, and in certain situations may produce reasonable results, their overall effectiveness in high-capacity wells is relatively limited when compared with other development methods. Other methods, as described below, are capable of removing more fine materials in less time and generally can produce higher specific capacities.

Well Development by Drilling Rig (Water Jetting):

Well Development by Compressor Machine:

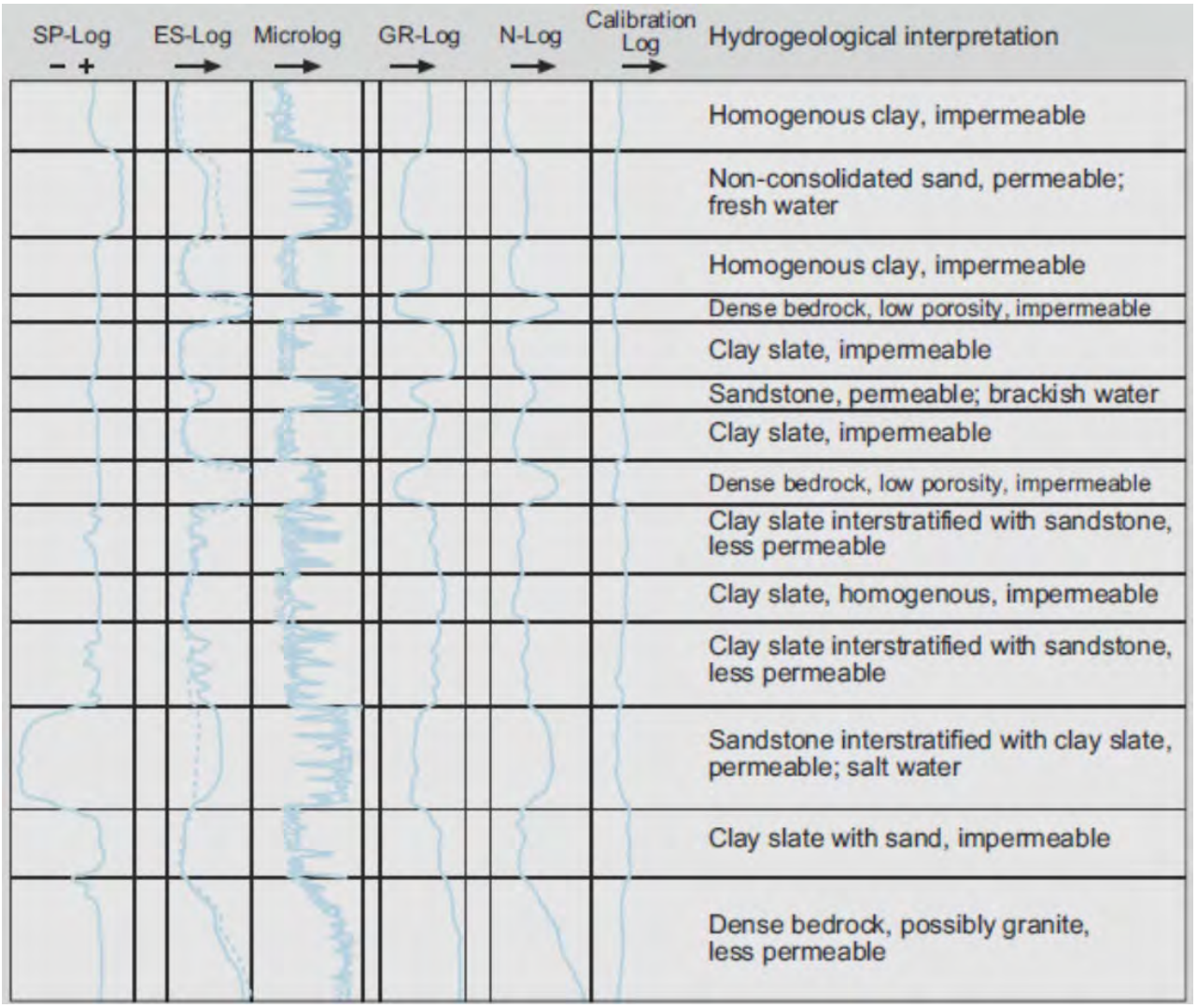

Table: Basic Well Logs and Their Correlations and Related Attributes (adapted from Schlumberger 1989,

After Behavior of logs in the formation and their interpretation

Terminology and Specifications of Construction Materials

Formations: (Ref. DTW Norms).

- Soft Formation: Clay, Silt, and Sand below fine gravel (up to particle size 4.75 mm)
- Medium Formation: fine gravel to medium (from particle size 4.75 mm to 16 mm)
- Hard Formation: above coarse gravel (>16 mm) and Rock strata)

Machinery and Tools:

Drill Machine: The selection of a boring drill rig and accessories depends upon the site geology, type, and depth of the well construction. The **FDO/GWUA** should select the drilling machine/rig as specified in the contract or by or in coordination and acceptance by the Employer's office and HG/SIH. The basic criteria for the selection of drilling machinery should be based on Table 1, however, the following tables should be studied before the selection of a suitable drilling machine, which also be considered by the employer office and **FDO/GWUA.**

Terminology and Specifications of Construction Materials

Formations: (Ref. DTW Norms).

- Soft Formation: Clay, Silt, and Sand below fine gravel (up to particle size4.75 mm)
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Table 2 Selection of Bit for Rotary Cum DTH Drilling

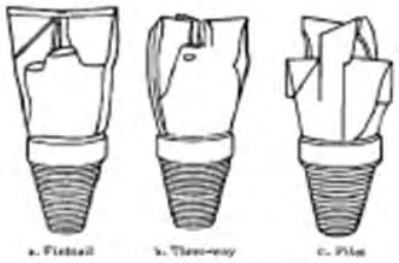
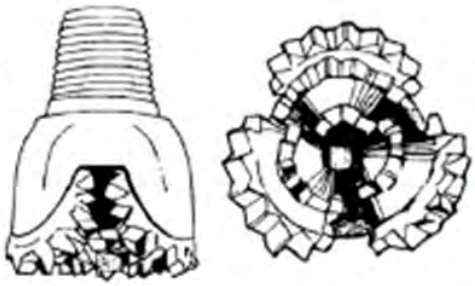
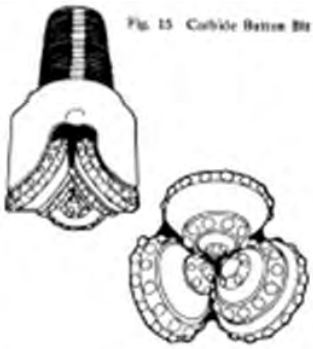
Formation	Drilling Method	Bit
Soft Formation	Mud Rotary	 Drag Bits are used used for very soft and unconsolidated formations such as clay and sand.
Medium Formation	Mud Rotary	 Tri-cone tooth bits are used for soft to hard formations. The tooth of cone is long for soft formation and short for hard formation.
Hard Formation	Mud Rotary	 Carbide Button Bit is used for hard formation. This type of bits needs the certain weight on bit in order to obtain the proper drilling progress (more than 3 tons). Therefore it is not suitable for small capacity drilling rigs.
Very Hard Formation	DTH	 The down the hole hammer (DTH) is suitable for very hard and consolidated formations. They are used for waterwell drilling in most of the areas of the mainland of Tanzania.

Table 11: Classification of drilling rigs

Table 12: Drilling Bit Drilling bit and machine Performance of Drilling Methods for Type of Formation

Type of Formation	Cable and Tool	Mud Rotary	DTH
Dune sand	Difficult	Rapid	Not recommended
Loose sand and gravel	Difficult	Rapid	Not recommended
Quicksand	Difficult, except in thin streaks. Requires a string of drive pipe.	Rapid	Not recommended
Loose boulders in alluvial fans or glacial drift	Difficult – slow but generally can be handled by driving pipe.	Difficult, Frequently impossible	Not recommended
Clay and silt	Slow	Rapid	Not recommended
Firm shale	Rapid	Rapid	Not recommended
Sticky shale	Slow	Rapid	Not recommended
Brittle shale	Rapid	Rapid	Not recommended
Sandstone – poorly cemented	Rapid	Rapid	Not recommended
Sandstone – well cemented	Fair	Slow	Not recommended
Chert nodules	Slow	Slow	Not recommended
Limestone	Slow	Rapid	Very Rapid
Limestone with chert nodules	Very Slow	Slow	Very Rapid
Limestone with small cracks or fractures	Very Slow	Slow	Very Rapid
Limestone cavernous	Very Slow	Slow to impossible	Difficult
Dolomite	Very Slow	Rapid	Very Rapid
Basalts, thin layers in sedimentary rocks	Slow	Slow	Very Rapid
Basalts – thick layers	Slow	Slow	Rapid
Metamorphic rocks	Slow	Slow	Rapid
Granite	Slow	Slow	Rapid

Source: Drillers Training and Reference Manual

- First Reaming by 2.5” Dia,
- Second Reaming by 6.5” Dia.
- Mechanical/Bogie bit of 7-5/8” Dia.

Equipment and accessories required are:

Electric Generator:	Pressure Guage
Welding generator:	Reinforced hose pipe
Generator:	Construction Materials:
Water Truck:	Blind Pipe:
Cargo Truck:	Screen:
Pickup Truck:	Flange:
Water Pump:	Nipple:
Jetting Machine:	Gasket:
Compressor Machine	Welding rod
Centrifugal pump:	Oxygen gas
Submersible Pump:	Acetylene gas
Orifice	Bucket
Water Table Indicator:	Linner:
4" pipe T:	Piston rod
6" pipe T	Gland packing
10: pipe T	Swivel packing
12 inch pipe T:	v-packing
14" Pipe T	valve/steel bell
tripod set	valve seat
Centrifugal pump	valve packing
Mud Pump	hex metaphosphate:
Diesel pump	welding rod
Submersible pump set	Pea Grave
Air Compressor	

Manpower Required:

- Technical Manpower Required: Site Hydrogeologist/Asst. Hydrogeologist (SI)
- Non-Technical Manpower Required: Skilled, Semi-Skilled, Unskilled (As necessary)

Well devlopmet by pump and tests for shallow and investigation tube wells : (Ref. ASTM D 5521)

Removal of dirt particles by over-pumping as water seems clean and free of turbidity up to 24 hrs.

- Material Required: Surface or Submersible pump of capacity 5-7 hp.
- Technical Manpower Required: Site Hydrogeologist/Asst. Hydrogeologist (SI)

Pumping test for unconfined aquifer: (Ref: ASTM D4043; D5912; D5920; Boulton; Neuman; Bouwer)

Continuous Pumping Test: A well is, first, constructed through the aquifer, of which the yield is to be estimated. A huge amount of water is drawn from the well, so as to cause heavy drawdown in its water level. The rate of pumping is changed and so adjusted that the water level in the well becomes constant. In this condition of equilibrium, the rate of pumping will be equal to the rate of yield, and hence, the rate of pumping will directly give us the yield of the well at a particular drawdown. But it is very difficult and almost impractical to adjust the rate, so as to keep the well water level constant.

- **Material Required**: Surface or Submersible pump of capacity 5-7 hp.
- **Technical Manpower Required:** Site Hydrogeologist/Asst. Hydrogeologist (SI)

Recuperation Test:

In this method, water is first of all drained from the well at a fast rate, so as to cause sufficient drawdown. The pumping is then stopped. The water level in the well will start rising. The rise is noted at regular intervals of time, till the initial level is reached. Knowing the area of the well and the rise of the water level, the volume of the water yielded in that given time interval, can be worked out at different drawdowns. It is found that the yield is higher at higher drawdowns. These tests are generally conducted during the driest periods of years, so as to know the yield under the worst conditions.

- **Material Required:** Surface or Submersible pump of capacity 5-7 hp.
- **Technical Manpower Required:** Site Hydrogeologist/Asst. Hydrogeologist (SI)

Well-Development: (Ref. ASTM D 5521)

Removal of dirt particles by over-pumping as water seems clean and free of turbidity up to 24 hrs.

- **Material Required:** Surface or Submersible pump of capacity 5-7 hp.
- **Technical Manpower Required**: Site Hydrogeologist/Asst. Hydrogeologist (SI)

Pumping tests

For unconfined aquifer: (Ref: ASTM D4043; D5912; D5920; Boulton; Neuman; Bouwer)

For confined aquifer: (Ref: ASTM D4043; D5912; D5920; Boulton; Neuman; Bouwer)

For leaky aquifer: (Ref: ASTM D4043; D5912; D5920; Boulton; Neuman; Bouwer)

Continuous Pumping Test: A well is, first, constructed through the aquifer, of which the yield is to be estimated. A huge amount of water is drawn from the well, so as to cause heavy drawdown in its water level. The rate of pumping is changed and so adjusted that the water level in the well becomes constant. In this condition of equilibrium, the rate of pumping will be equal to the rate of yield, and hence, the rate of pumping will directly give us the yield of the well at a particular drawdown. But it is very difficult and almost impractical to adjust the rate, so as to keep the well water level constant.

- **Material Required:** Surface or Submersible pump of capacity 5-7 hp.
- **Manpower Required**: Site Hydrogeologist/Asst. Hydrogeologist

Step Draw Down Test for shallow Tubewell:

Recovery Test for Shallow Tubewell:

In this method, water is first of all drained from the well at a fast rate, so as to cause sufficient drawdown. The pumping is then stopped. The water level in the well will start rising. The rise is noted at regular intervals of time, till the initial level is reached. Knowing the area of the well and the rise of the water level, the volume of the water yielded in that given time interval, can be worked out at different drawdowns. It is found that the yield is higher at higher drawdowns. These tests are generally conducted during the driest periods of years, so as to know the yield under the worst conditions.

- **Material Required:** Surface or Submersible pump of capacity 5-7 hp.
- **Manpower Required:** Site Hydrogeologist/Asst. Hydrogeologist

1610 MEASUREMENT AND PAYMENT

All the items of work in this Section shall be measured in their respective units as mentioned in the BoQ. The payments for these items of work shall be made at the respective unit rates mentioned in the BoQ of contract document. The contract unit rates shall be the full and the final compensation to the Contractor as per Clause 115.

SECTION 1700- BIO ENGINEERING WORKS

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1703 PROVISION OF PLANT CUTTINGS 17-3

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1705 NURSERY OPERATION AND MANAGEMENT 17-10

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Ministry of Energy, Water Resources and Irrigation
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1701 SCOPE

This Section covers all components of bio-engineering works such as provision of seed and plant cutting, nursery construction and operation, slope preparation for planning, site planting and sowing, jute netting, gabion wire bolsters, wire netting, site protection, aftercare/maintenance, etc.

1702 PROVISION OF SEEDS

The Contractor shall provide or collect seeds of the required species and quantities in accordance with the requirements described hereafter, as and when required. He shall supply all necessary expertise, resources and facilities to ensure that these requirements are of a high quality and are met fully as desired.

The Engineer shall give indications as to the expected amounts of seeds required and the time of availability. But it shall be the Contractor responsibility to ensure that adequate quantities of seeds are obtained in a timely manner.

The weight to be specified shall be for sun-dried seeds separated completely from fruiting bodies and other unwanted parts, and ready for storage and subsequent sowing. There is usually large discrepancy between this weight and that of the freshly collected, untreated fruits.

Should the Contractor be unable to supply the specified seeds, the advice of the Engineer should be sought. The Engineer may approve other substitute species, if found appropriate. If seeds required are available in the nearby markets, the contractor shall supply the required seeds in required quantity as mentioned in the contract from the market as directed by the Engineer. Otherwise, Seed shall not be obtained commercially from the market without the Engineer's written approval.

(1) Grass Seed Collection

(a) The species of grass seeds to be collected shall be determined by the Engineer. The Contractor shall be responsible for identifying and securing seed sources, unless otherwise directed by the Engineer. As far as practicable, seeds shall be collected within or in close proximity to the intended area of use—preferably within the project command area, river corridor, or project site.

(b) If the Engineer does not specify the species, then the current approved list of bio- engineering plants, as determined by the Environment/ Bio-Engineering Section of the Department of Water Resources and Irrigation (DWRI).

(c) Seeds shall be collected from as many individual plants as possible. Seeds shall be collected from the largest and most vigorous plants.

(d) The Contractor shall under no circumstances damages or remove the roots of grass plants while collecting seed. The Contractor shall be responsible for safety measures and for making all necessary arrangements with landowners, farmers and the local District Forest Office, as applicable, before the collection of seeds.

(e) Seeds shall only be collected when fully ripe. Seeds collected early shall not be accepted. The Contractor shall be held liable if the germination rate of seeds is lower than 70%.

(f) Immediately after collection, seeds shall be separated from flower heads by the method normally used by farmers for other grasses. Once separated, the seeds shall be sun-dried before storage.

(g) Seeds shall be stored in a cool, dry, ventilated building with adequate precautions taken against pests. Containers shall be raised above the floor. They shall not be kept in the same building in which materials like cement, or any chemicals, fuels or lubricants are stored. Grass shall be stored in bags made of cotton. Seeds shall be carefully inspected on a weekly basis to ensure that there is no deterioration or moulds formation, or pest attack. Seeds shall only be stored after they have been properly dried in the sun beforehand.

(h) Measurement and Payment: Works shall be measured on the basis of actual quantity collected,

weighed in Kilogram and accepted by the Engineer. The quantities thus measured shall be paid at the unit rates shown in the Bill of Quantities. Such payment shall be the full and the final compensation to the Contractor for making arrangements of collection location, provision of safety measures, collection of seeds, separation of seeds, preparation of seeds, sun drying, packing and providing the seeds as per these Specifications.

(2) Tree and Shrub Seed Collection

(a) The species of tree and shrub to be collected shall be determined by the Engineer. The Contractor shall be responsible for determining seed sources, though these may be specified by the Engineer's instructions. Seeds shall normally be collected in or very close to the working area.

(b) If the Engineer does not specify the species, then the current approved list of bio- engineering plant, as determined by the Environment/ Bio-Engineering Section of the Department of Water Resources and Irrigation (DWRI).

(c) Seeds shall be collected from as many individual plants as possible. If any event, they shall be collected from at least ten individual plant. The plants from which the seeds are collected shall show vigorous growth and good form. Mis-shaven and stunted plants shall be discarded.

(d) The Contractor shall under no circumstances damage plants while collecting seed. The Contractor shall be responsible for making all necessary arrangements with and owners, farmers and the local District Forest Office, as applicable, before the collection of seeds.

(e) Appropriately trained personnel with appropriate equipment shall be employed while collecting the seeds. It shall be the Contractor's responsibility to ensure safe working conditions for his employees or Sub-contractors.

(f) Seeds shall only be collected when fully ripe. Seeds collected early shall not be accepted. The Contractor shall be held liable if the germination rate of seeds is lower than 80%.

(g) Immediately after collection, seeds shall be separated from fruit by the method normally used by farmers and foresters for this purpose; this shall depend on the individual species. Once separated, the seeds shall be sun-dried before storage.

(h) Seeds shall be stored in a cool, dry, ventilated building with adequate precautions taken against pests. Containers shall be raised above the floor. They shall not be kept in the same building in which materials like cement, or any chemicals, fuels or lubricants are stored. If kept in sealed bag, the seeds shall be carefully inspected on a weekly basis to ensure that there is no deterioration or mould formation or pest attack. Seeds shall only be stored after they have been properly dried in the sun beforehand.

(i) Measurement and payment: works shall be measured on the basis of actual quantity collected, accepted and weighed in Kilogram. The quantities thus measured shall be paid at the unit rates shown in the Bill of Quantities. Such payment shall be the full and the final compensation to the Contractor for making arrangements of collection location, provision of safety measures, collection of seeds, separation of seeds, preparation of seeds, sun drying, packing and providing the seeds as per these Specifications.

1703 PROVISION OF PLANT CUTTINGS

Species of plants to be collected for vegetative propagation shall be determined by the Engineer. The Contractor shall be responsible for determining plant material sources, through these may be specified by the Engineer's instructions. Plants shall normally be collected in or very close to the working area.

If the Engineer does not specify the species, then the current approved list to bio-engineering plants, as determined by the Environment/ Bio-Engineering Section of the Department of Water Resources and Irrigation (DWRI).

Government of Nepal
Ministry of Energy, Water Resources and Irrigation
Department of Water Resources and Irrigation
Jawalakhel, Lalitpur

(1) Provision of Grass Cutting

(a) Cuttings of various types shall be taken from grass species, which are known to propagate.

(b) Cuttings shall be made from as many healthy individual plants as possible. The plants from which the cuttings are taken shall show vigorous growth and good form. Grass clumps showing stunted growth shall not be considered as sources.

(c) Apart from the clumps, which are dugs up to make cutting, the contractor shall under no circumstances damage other plants. The Contractor shall be responsible for making all necessary arrangements with landowners, farmers and the local District Forest Office, as applicable before the making of hardwood cuttings.

(d) The type of cuttings to be made shall depend on the species and shall be as shown in Table 17.1. If the species used is not listed here, then the latest technical information provided by the Environment & Disaster Management Section. If the species is still not covered, then stem and root slip cuttings shall be used.

Table 17.1: Type of Grass Cutting

Local name	Botanical Name	Best Propagation	Details
Amliso	Thysanolaena maxima	Rhizome cutting	Stem: 100-150 mm; rhizome: 50-80 mm
Babiyo	Eulaliopsisbinata	Slip cutting	Stem: 100-150 mm; root: 20-40 mm
Dhonde	Neyraudiareynaudiana	Rhizome/stem cutting	Rhizome cutting: - Stem: 100-150 mm: rhizome: 40:50 mm Stem cuttings: 2 nodes plus 20 mm each sides
Kans	Sacccharum spontaneum	Slip cutting	Stem: 100-150 mm; root: 30-40 mm
Khar	Cymonpogon microtheca	Slip cutting	Stem: 100-150 mm; root: 30-40 mm
Khus	Vetiverlowsonil	Slip cutting	Stem: 100-150 mm; root: 30-40 mm
Napier	Pennisetumpurpureum	Stem cutting	Single node: - 1 node with 30- 40 mm top and 100-150 mm bottom; Double nodes:- 2 nodes plus 30-40 mm each sides
Narkat	Aruundoclonax	Stem/Slip cutting	Single cutting: - 2 node plus 30-40 mm each sides Slips cuttings: - Stem: 100- 150 mm; root:30-40 mm each sides
Padang bans	Himalayacalamus hookerianus	Rhizome	Stem:750-1200 mm; rhizome: 100-200 mm.
Phurke	Arunduellanepalensis	Rhizome cutting	Stem:100-150 mm; rhizome: 30-40 mm.
Sito	Neyraudiaarundinacea	Rhizome cutting	Stem:100-150 mm; rhizome: 30-60 mm.
Titenigalo	Drepanostachyum intermedium	Rhizome	Stem:50-1200 mm; rhizome: 100-200 mm

(e) Where roots are required for the cuttings, grass clumps shall be carefully dug up. They shall not be pulled hard so as to damage the material. They shall be separated carefully by hand, using a sharp khukuri or knife where necessary. There shall be no tearing of the plant fabric.

(f) Stem cutting shall be made using sharp secateurs or khukuri. The tip cut shall be made at right angles to the stem and the bottom cut shall be made at 45o C to the stem.

(g) Once cuttings have been made, they shall be wrapped in wet hessian jute immediately. At all times, cuttings shall be kept moist and as cool as possible, and shall be wrapped in wet hessian between all operations such as digging out of the ground, splitting out, trimming and planting. If the hessian jute is not easily available, the cuttings shall be covered with the thick blanket of off-cut part of vegetation such as Titepati and Banmara. For this prior approval of the Engineer shall be required. Under any circumstances, all cuttings shall be planted the same day that they are made.

(h) Measurement and Payment: Measurement of grass cuttings shall be made on the basis of actual numbers of slip or cutting prepared, counted on site and accepted. The quantities thus measured shall be paid at the unit rate shown in the Bill of Quantities. Such payment shall be the full and the final compensation to the Contractor for all arrangements for uprooting of grass clumps, collection of materials for cuttings and preparation and providing the cuttings as per these Specifications.

(2) Provision of Hard wood cuttings

(a) Hardwood cuttings shall be taken from shrubs and trees species which are known to propagate easily by vegetative means.

(b) Cuttings shall be made from as many healthy individual plants as possible. The plants from which the cuttings are taken shall show vigorous growth and good form. Mis-shaven and stunted plants shall not be considered as source.

(c) Apart from the branches from which cuttings are taken, the Contractor shall under no circumstances damage plants while taking cuttings. The Contractor shall be responsible for taking safety precautions and for making all necessary arrangements with landowners, farmers and the local District Forest Office, as applicable, before the making of hardwood cuttings.

(d) Hardwood cuttings shall be made from stems which are between 6 and 18 months old. Materials outside this range shall not be used. The Contractor shall be held liable if the success rate of cuttings is lower than 70%.

(e) Hardwood cutting shall be made using sharp secateurs or a sharp saw. The top cut shall be made at right angles to the stem and the bottom cut shall be made at 45° to the stem. Under no circumstances shall there be any damage to the bark of the cutting.

(f) Hardwood cuttings, which are to be planted in the nursery for later multiplication, shall be normally 150 to 200 mm in length and 20 to 30 in diameter. This size shall not be exceeded for the majority of species unless specified or approved by the Engineer.

(g) Hardwood cuttings which are to be used in brush layering, palisades and live stakes shall normally be 450 mm for brush layering on flood protection dykes, guide bunds, and canal embankment slopes, 600 mm for brush layering on landslide debris, 600 mm for palisades and 20 to 40 mm in diameter. This length of cuttings shall not be exceeded for the majority of species unless specified or approved by the Engineer.

(h) The size of cuttings shall be of a minimum length of 1000 mm and 50 mm of diameter for fascines. All the small branches growing from the main branch shall be preserved. Those small branches contain the first sprouting buds which will help to keep alive the main branches as they are buried in the ground.

(i) A number of species can be propagated using large truncheon cuttings. In this category fall chuletro (Brassaiopsishainla), dabdabe (Garugapinnata), kavro (Ficuslacor), phaledo (Erythrina species) and Gliricidiasepium. Hardwood cuttings for these species shall be in the range of 2000 to 2500 mm in length and 50 to 80 mm in diameter unless otherwise specified.

(j) All trunchen cuttings shall be covered with long mulch during transportation and storage. Under any circumstances, all cuttings shall be planted within two days that they are made.

(k) Measurement and Payment: Measurement of hardwood cuttings shall be made on the basis of actual numbers of cutting prepared, counted on site and accepted.

(l) The quantities thus measured shall be paid at the unit rate shown in the Bill of Quantities. Such payment shall be the full and the final compensation to the Contractor for all arrangements for collection of materials and preparation of cuttings and providing the cuttings as per the Specifications.

(3) Provision of Bamboo Cutting

(a) Bamboo cuttings shall be propagated by two different methods i.e. traditional method and single node culm cuttings method.

(b) Cuttings shall be made from as many healthy individual culms as possible. The culm from which the cuttings are taken shall show vigorous growth and good form having heavily branched. Mis-shaven and stunted plants shall not be considered as source.

(c) The Contractor shall be responsible for taking safety precautions and for making all necessary arrangements with landowners, farmers and the local District Forest Office, as applicable, before making of cuttings. The traditional method which will require to take the whole culm and mother rhizome may eradicate the further development of clump. In this case, the contractor shall be responsible for making aware of such probability to the owner before taking the rhizomes from such clump. However, if the sourcing clumps are growing on steep slopes, the contractor shall not take more than 10% culm from the sourcing clump.

(d) The type of cuttings to be made which depend on the species shall be as shown in Table 17.2. Single node culm cuttings or traditional rhizome cuttings shall be made from the culm which are between 2-3 years old. Materials outside this range shall not be used without the prior approval of the Engineer. The Contractor shall be held liable if the success rate of single node culm cuttings is lower than 60% and in the case of or rhizome cuttings not surviving 100%.

(e) Single node cuttings shall be made using sharp log saw. The top and bottom cut shall be made at right angles to the stem. Under no circumstances shall there be any damage to the bud and internode section of culm.

(f) The rhizome cuttings shall be made using sharp log saw, axe and secateurs.

(g) Once cuttings have been made, they shall be wrapped in wet hessian jute immediately. At all times, cuttings shall be kept moist and as cool as possible, and shall be wrapped in wet hessian between all operations such as taking from the parent plant, transporting and planting. Under any circumstances, all cuttings must be planted within two days of that they are made.

(h) Measurement and Payment: Measurement of bamboo cuttings shall be made on the basis of actual numbers of cuttings prepared, counted on site and accepted. The quantities thus measured shall be paid at the unit rate shown in the Bill of Quantities. Such payment shall be the full and the final compensation to the Contractor for all arrangements for purchasing of bamboo and preparation of cuttings and providing the cuttings as per the Specifications.

(i) Bamboo plantation using bamboo cutting is effectively used for the protection of riverbank erosion as bamboo plantation along the riverbank makes the bank rigid and unerodable. Such bamboo plantation along the riverbank shall be carried out following the usual process of plantation and their subsequent protection by means of fencing (Bamboo fencing).

Table 17.2: Types of Bamboo Cutting

Local name	Botanical Name	Best Propagation	Details
Choya/ tama bans	Dendrocalamu s hemiltonil	Single Node ulm/ rhizome cutting	Single node culm cuttings: - 1 node and 150 mm of each side, straight and fine cut, main branch should be 200-300 mm long; Rhizome cuttings: - Culm 2500-

			3000- mm length, leave all branches with no leaf (manually flushed); rhizome: 300-500 mm.
Dhanu bans	Bambusabalcooa	Single Node culm/ rhizome cutting	Single node culm cuttings: - 1 node and 150 mm of each side, straight and fine cut, main branch should be 200-300 mm long; Rhizome cuttings: - Culm 2500-3000 mm length, leave all branches with no leaf (manually flushed); rhizome: 300-500 mm
Kalo bans	Dendrocalamus hookeri	Single node culm/ rhizome cutting	Single node culm cuttings: - 1 node and 150 mm of each side, straight and fine cut, main branch should be 200-300 mm long; Rhizome cuttings: - Culm 2500-3000 mm length, leave all branches with no leaf (manually flushed); rhizome: 300-500 mm
Mal bans	Bambusanutans	Single node culm/ rhizome cutting	Single node culm cuttings: - 1 node and 150 mm of each side, straight and fine cut, main branch should be 200-300 mm long; Rhizome cuttings: - Culm 2500-3000 mm length, leave all branches with no leaf (manually flushed); rhizome: 300-500 mm
MA lingo bans	Arundinaria maling	Rhizome cutting	Rhizome cuttings: - Culm 2500-3000 mm length, leave all branches with no leaf (manually flushed); rhizome: 300- 500 mm
Nibha/gopi bans	Ampelocalamus pattellaris	Single node culm/ rhizome cutting	Single node culm cuttings: - 1 node and 150 mm of each side, straight and fine cut, main branch should be 200-300 mm long; Rhizome cuttings: - Culm 2500-3000 mm length, leave all branches with no leaf (manually flushed); rhizome: 300-500 mm
Nigalo bans	Phyllostrachys	Rhizome cutting	Rhizome cuttings: - Culm 2500-3000 mm length, leave all branches with no leaf (manually flushed); rhizome: 300- 500 mm
Parayana bans	Drepanoschyum hookerieanum	Rhizome cutting	Single node culm cuttings: - 1 node and 150 mm of each side, straight and fine cut, main branch should be 200-300 mm long; Rhizome cuttings: - Culm 2500-3000 mm length, leave all branches with no leaf (manually flushed); rhizome 300-500 mm:
Tharu bans	Ambulated	Single node culm/ rhizome cutting	Single node culm cuttings: - 1 node and 150 mm of each side, straight and fine cut, main branch should be 200-300 mm long; Rhizome cuttings: - Culm 2500-3000 mm length, leave all branches with no leaf (manually flushed); rhizome: 300-500 mm

1704 NURSERY CONSTRUCTION

The Contractor shall provide nurseries to contribute stocks of grasses, shrubs and trees for planting operations as required by the Engineer. This shall be done according to the specifications described

hereunder, as and when required by the Engineer. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.

The Contractor shall note that the establishment and effective operation of plant nurseries is a skilled business requiring experienced and trained staff. These specifications alone do not provide all the information needed to set up and run nurseries. The Contractor shall seek the advice of specialist agencies and shall refer to the large number of reference books available on the subject.

The purpose of a nursery shall be to supply good quality, healthy plants of the correct type and species at the precise time they are required.

(1) Nursery Establishment

(a) The Contractor shall provide nursery facilities adequate to supply all of the stock required for planting operations. Alternatively, he may procure planting stock from elsewhere at the time of site planting, provided it is of a standard acceptable to the Engineer and as described hereunder.

(b) In selecting a site for a nursery, if not instructed by the Engineer, the Contractor shall fulfil the following requirements.

(i) Nurseries shall be as close as possible to all sites to be planted. They shall be at the same altitude as, and in an identical climatic area to the sites to be planted.

(ii) Wherever possible, nurseries shall be established on land owned by the Department of Water Resources and Irrigation (DWRI), canal right-of-way (ROW), or irrigation headworks premises if it is available and biophysically suitable. If it is not, other land of His Majesty's Government shall be used if it is available.

(iii) Nurseries shall have a reliable and adequate supply of water which remains constant throughout the later part of the dry season.

(iv) Nurseries shall have all weather vehicular access.

(v) Nurseries shall have a perimeter of stock-proof fencing, effective against all domestic animals.

(vi) Nurseries shall have a weather- and pest-proof office cum seed store and proper storage facilities for seed. Seed shall be kept cool, dry and in sealed bag, as specified in Sub-clauses 1702 (1) and 1702 (2).

(vii) All nurseries shall be provided with at least two above-ground compost bays, built of stone, brick or timber.

(viii) Where a nursery is established on a slope exceeding 2°, the ground shall be levelled by terracing before beds are constructed.

(ix) A constant staff of qualified and experienced people must be provided.

(x) There shall be adequate space in each nursery location for all operations to be performed in the cycle of work. In particular, all plants shall be spaced out periodically as they grow and there shall be adequate bed area to accommodate them.

(2) Construction of Nursery Beds

(a) Nursery beds shall be made in a different way according to their purpose. The Contractor shall ensure that there are adequate beds available for all the operations to be undertaken in the nursery.

(b) There shall be paths around all beds to ensure the best possible access for operations such as weeding and watering.

(c) Table 17.3 summarizes the construction details of the five main bed types, which are described in full in paragraphs (d) to (h).

Table 17.3: Construction Details of Nursery Beds

Bed type	Bed size	Details of construction
Beds for bare grass seeding, grass slips propagation	Bottom width 1200 mm and top width 1000 mm x 200 mm high	Bottom of the bed should be compacted making a camber to facilitate the drainage; 50 mm washed gravel placed above the ground; then 50 mm of 1:1 mix of soil and compost; and topped with 100 mm of 3:1 mix of sieved forest topsoil and washed sand.
Beds for bare root tree seedlings	Bottom width 1200 mm and top width 1000 mm x 200 mm high	Bottom of the bed should be compacted making a camber to facilitate the drainage; 50 mm washed gravel placed above the ground; then 50 mm of 1:1 mix of soil and compost; and topped with 100 mm of 3:1 mix of sieved forest topsoil and washed sand.
Seed beds for tree/shrub seedling	1000 mm wide (external), 170 mm high with edging; Shade 900 mm of height on the lower side and 1200 mm higher side.	Bed should be providing with brick, flat stone or plank edging as determined by the Engineer; shade should be provided of waterproof materials or as determined by the Engineer; 50 mm of washed gravel placed above the compacted and cambered ground; then 50 mm un-sieved forest soil 50 mm of 1:3 mix of sieved forest soil and washed sand; and topped with 20 mm of washed, sieved and sterilized sand.
Stand out beds for tree/shrub Seedlings.	1000 mm wide (external), 170 mm high with edging; Shade 900 mm of Height on the lower side and 1200 mm higher side.	Bed should be providing with brick, flat stone or plank edging as determined by the Engineer; shade should be provided of waterproof materials or as determined by the Engineer; 50 mm of washed gravel placed above the compacted and cambered ground
Bead for the propagation of bamboo culm cutting and stool bed for tree and shrub cutting	Bottom width 1200 mm and top width 1000 mm x 200 mm high	Ground below the bed is dug to a depth of 300 mm. Bed is made with 100 mm of un sieved soil (lower) and 200 mm of sieved soil (upper). A bund of 100 mm high is formed around the edge. 1500 mm high shade of bamboo frame jute is made.

(d) Grass beds shall be constructed to hold grass seeds; grasses being propagated by vegetative means. These can be of any practical length but shall be flat and of 1200 mm base width and 1000 mm of top width on compacted and a cambered ground. They shall rise to a height of 200 mm above the surrounding ground. They shall be made up as follows: 50 mm of washed gravel is placed above the ground; then 50 mm of 1:1 mix of soil and compost; and the bed is topped with 100 mm of 3:1 mix of fertile, loamy forest topsoil and washed sand. All sieving shall be done with a mesh size of 2 mm or smaller.

(e) Bare root beds shall be constructed to hold tree transplanted from the seed beds. These can be of any practical length but shall be flat and of 1200 mm base width and 1000 mm of top width on compacted and a cambered ground. They shall rise to a height of 200 mm above the surrounding ground. They shall be made up as follows: 50 mm of washed gravel is placed above the ground; then 50 mm of 1:1 mix of soil and compost; and the bed is topped with 150 mm of 3:1 mix of fertile, loamy forest topsoil and washed sand. All sieving shall be done with a mesh size of 2 mm or smaller.

(f) Seed beds shall be made very carefully for germinating small seeds of shrubs and trees. These can be of any practical length but shall be flat and of one metre in width on compacted and a cambered ground. They shall rise to a height of 170 mm above the surrounding ground and provided with shadings as per the details given in the following paragraph.

(g) They shall be made up as follows: 50 mm of washed gravel placed on the ground; then 50 mm of unsieved forest soil; 50 mm of 1:3 mix of forest soil and washed sand; and the bed is topped with 20 mm of washed, and sterilized sand. All sieving shall be done with a mesh size of 2 mm.

(h) Standout beds shall be constructed to hold seedlings in polythene pots. These can be of any practical length but shall be flat and of one meter width. Bed floors shall be above surrounding ground level and they shall have a 50 mm layer of washed gravel on the compacted and cambered ground. They shall have a surround, preferably made from flat stones, plank or bricks. The bed shall then be covered with the highly porous shadings as per the details provided in the following paragraph (i).

(i) Beds for the propagation of bamboo culm cuttings and stool cuttings of trees and shrubs, shall be made specially. These can be of any practical length but shall be flat and of 1000 mm width at top and 1200 width at bottom. They shall rise to a height of 300 mm above the surrounding ground. They shall be made up as follows: the ground below the bed is dug to a depth of 300 mm; the bed itself is then made with 100 mm of unsieved soil on the original surface, and 200 mm of soil above this. All soil sieving shall be done with a mesh size of 2 mm or smaller. Finally, a bund of 100 mm high shall be formed around the edge.

(j) Shades shall be constructed over the beds and kept in position over delicate seedlings during hours of intense sunlight, according to need. Shades shall be 900 to 1200 mm above the ground, and angled so as to be effective for as much of the day as possible (i.e. with the lower side to the south). Bamboo strips laced together with nylon string are particularly suitable in most cases; but over tree and shrub seed beds, thatched shades with a polythene lining shall be used.

(k) Measurement and Payment: Work to be measured shall be the actual top area in sq. m of beds constructed on site and accepted. Only the finished area of the beds shall be considered after the completion of its shades. However, despite the fact that shades will be covering larger area than the beds, the final measurement shall be governed by the area of the top of the bed for payment. The payment shall be the full and the final compensation to the Contractor for providing all materials to be incorporated, ail labour, tools, equipment and incidentals to complete the works of Nursery establishment and construction of Nursery beds as per these Specifications.

1705 NURSERY OPERATION AND MANAGEMENT

(a) The contractor shall operate the nursery according to a high standard. The nursery shall be staffed well-tended at all times. It shall be maintained in clean, tidy and efficient manner at all times. Plants shall always be healthy and vigorous.

(b) Due to the nature of bio-engineering works, nurseries shall normally be operated and managed by small local contractors with a range of agricultural skills provided it is specified in the Contract. If provided in the Contract, nurseries may also be managed by the Groundwater/Irrigation Management Division Office or Water Users Association (WUA).

(c) Plants shall be kept properly weeded at all times.

(d) Watering, as required for good plant growth, shall be carried out regularly in the cool of the evening between sunset and dusk. The Contractor shall ensure that the soil in all beds is kept moist but not saturated at all times. Beds shall be kept moist even when empty, so that the soil is kept in good condition.

(e) The timing of nursery operations shall be of the utmost importance. Activities such as seed sowing and the taking of cutting shall be carried out within the critical few weeks when they will yield the desired results. Most other operations, such as spacing out, root pruning and watering, shall also be

carried out in a timely manner in accordance with the Nursery Calendar published by the Environment & Disaster Management Section of the Department of Water Resources and Irrigation (DWRI). The Contractor shall be responsible to keep works to the strict schedule required and under no circumstances to permit delays.

(f) Measurement and Payment: The basis of measurement shall be the actual numbers of plants counted, certified and accepted by the Engineer. Quantities measured as above shall be paid at the unit rates entered in the Bill of Quantities. Such payment shall be the full and the final compensation to the Contractor for executing all the works as specified in these Specifications.

(1) Nursery Production of Grass

(a) Grass shall be propagated in nurseries either by seeding in carefully prepared beds or by vegetative propagation.

(b) Where grass seeding is required in the nursery, finely sieved fertile soil mixed with clean sand to a texture of sandy loam shall be placed in beds before the seeds are sown. Seeds shall be covered with a sheet of hessian jute until they have germinated, then it shall be carefully removed. Watering of fresh seedlings shall be done by a fine spray and not by the rose of a watering can.

(c) Grasses to be propagated by vegetative methods shall be of the species instructed. The Contractor shall obtain adequate quantities of the plant material required, but under no circumstances shall the to cause serious depletion of grass stocks in any steep or erosion-prone area.

(d) Vegetative propagation shall normally be by rhizome cuttings. With this method, the grass shall be treated in exactly the same way as a bamboo being propagated by the traditional Nepalese farmer's technique. A clump shall be carefully dug up and brought to the nursery, being kept cool and damp at all times. Stems shall be cut above the first or second node above the ground: this usually gives a length of 100 to 200 mm. The clump shall be separated carefully, with the minimum of damage to the rhizomes and fine roots. Slips shall be separated out which keep a length of stem and about 50 mm of the rhizome. Each slip shall have some buds on the rhizome, but in some grasses these can be difficult to see. The slips shall be planted with the soil surface at the same level as it was originally, in rows at 200 mm centres; slips shall be at 200 mm centres within the rows. A sheet of hessian jute shall be placed over the tops of the cuttings. When the new shoots are about 50 mm long, it shall be removed.

(e) Every two to three months, all grasses shall be lifted from the beds, split carefully and replanted. It is normal that, once split out, three times the previous bed area is required. This is a standard practice to bulk up the supply of planting stock without having to degrade the natural vegetation cover in the region of the nursery.

(f) Measurement and payment: The basis of measurement shall be the actual area of live grasses covered surfaces in sq. m. Quantities measured as above shall be paid at the unit rates entered in the Bill of Quantities. Such payment shall be considered the full and the final compensation to the Contractor for executing all the works as specified in these Specifications.

(2) Nursery Production of Trees and Shrubs in Polypots

(a) Trees and shrubs shall be seeded either in seed beds or directly in polythene pots ("polypots"). Finely sieved fertile soil mixed with clean sand to a texture of sandy loam shall be placed in well shaded beds for seeding. Watering of fresh seedlings shall be by a fine spray, and not by the rose of a watering can.

(b) All pants shall be grown on in pots of dimensions 100 x 180 mm (4 x 7 inches) or greater when laid flat. The pots shall be of black, 200-gauge polythene. They shall have adequate drainage holes at the bottom and be filled with fertile forest topsoil mixed with clean sand to a texture of sandy loam.

(c) Roots protruding from the bottom of pots shall be pruned with a razor blade on regular basis which shall not exceed weekly and may need to be more frequent. Protruding roots shall never be allowed

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to become more than 25 mm in length.

(d) When polypot seedlings begin to compete with each other for light, they shall be re- spaced as required. This would typically mean doubling the bed space occupied by the plants.

(e) To be acceptable for planting on site, trees and shrubs shall be healthy, vigorous and showing no signs of damage, wilt, irregular growth, fungal or pest attack, or nutrient disorders. They shall be at least 300 mm in height above soil surface level and of good form. The roots shall be in good condition and there should be no signs of disturbance to the soil in the polythene pot, even after transport to site.

(f) Measurement and Payment: The basis of measurement shall be the actual numbers of plants counted, certified and accepted by the Engineer. Quantities measured as above shall be paid at the unit rates entered in the Bill of Quantities. Such payment shall be the full and the final compensation to the Contractor for executing all the works as specified in these Specifications.

(3) Nursery Production of Hardwood Plants by Vegetative Methods

(a) Trees and shrubs which can be propagated by vegetative methods may be specified by the Engineer. The Contractor shall produce these by the appropriate method, as required.

(b) All cuttings and stools shall be made as specified in Sub-clause 1703(2) and planted in fertile soil beds of the type specified in Sub-clause 1704 (2).

(c) Cuttings shall be planted 300 mm apart in holes slightly larger than their diameter. They shall be placed at such a depth that only one bud remains above the soil surface (i.e. about 30 mm of the cutting).

(d) When plants compete with each other for light, they shall be cut back as necessary to be acceptable for planting on site, trees and shrubs produced in this way must be healthy, vigorous and showing no signs of damage, wilt, irregular growth, fungal or pest attack, or nutrient disorders. They shall be at least 500 mm in height above soil surface level and of good form.

(e) Measurement and Payment: The basis of measurement shall be the actual numbers of plants counted, certified and accepted by the Engineer. Quantities measured as above shall be paid at the unit rates entered in the Bill of Quantities. Such payment shall be the full and the final compensation to the Contractor for executing all the works as specified in these Specifications.

(4) Extraction of Plants from the Nursery

(a) The Contractor shall be responsible for extracting plants from nursery beds and preparing them ready for transport. They shall be extracted from the beds only on the morning that they are required for planting on site.

(b) Plants shall be hardened off, starting at least two weeks before they are to be taken out of the nursery. This process shall require a gradual reduction in the amount of watering and shading. The aim is to prepare them for transfer to a much more hostile location.

(c) The night before the plants are to be lifted, they shall be thoroughly watered. This is to make the soil softer and ease the business of extracting the roots.

(d) Plants growing in soil beds shall be carefully lifted from the soil. There shall be no pulling of stems or roots, but they shall be dug out and extracted with no strain on any part of the plant.

(e) Plants from soil beds shall be wrapped in wet hessian jute. Hardwood plants shall have a ball of soil around the roots. Grass clumps can have most of the soil shaken or washed off.

(f) Polypot seedlings shall be lifted and stacked neatly in metal or wooden trays. They shall always be lifted by the pot and never by the stem or leaves.

(g) All plants shall to be kept moist, in a cool, shady place, until they are loaded for transport to site. In the vehicle, they shall not be stacked high. For transport on rough roads, they shall be packed in

carefully so that they do not fall over or roll around. The vehicle shall be shaded.

(h) Measurement and Payment: The basis of measurement shall be the actual numbers of plants counted, certified and accepted by the Engineer. Quantities measured as above shall be paid at the unit rates entered in the Bill of Quantities. Such payment shall be the full and the final compensation to the Contractor for executing all the works as specified in these Specifications.

(5) Compost and Mulch Production

The Contractor shall produce compost and mulch for nursery or site operations. It shall be produced in a timely manner, in the quantities red. Compost is normally required to sustain the long term fertility of nursery beds. Mulch may also be used in then nursery, but normally produced to enhance site planting works, particularly the direct seeding of grass.

(a) Compost and mulch shall be made from annual and perennial weeds of poor rooting characteristics, such as ban mara (Eupatorium adenopherum) and tite pate (Artemesiavulgans). The greenery shall be collected when there is most material available but before it forms seeds. This is most often in Shrawan and Bhadra.

(b) Collected material shall be chopped finely and stored in a mound, compost bay or pit. The maximum size for chopped compost is 50 mm; the maximum size for chopped mulch is 150 mm.

(c) Both compost and mulch shall be kept moist but not waterlogged and in an aerated condition. They shall be completely turned once a month on a regular schedule. Compost can have cow manure mixed in to assist the process of decomposition.

(d) Neither compost nor mulch shall be applied until they are fully rotted. By this time, they shall be black and the parts of individual plants shall be indistinguishable. Early application shall not be allowed as this can lead to a nutrient loss in the soil if microbes extract nitrogen to decompose the added organic material.

(e) Measurement and Payment: The basis of measurement shall be the actual quantity of compost and mulch provided, accepted and certified by the Engineer in cu. m. or kg. Quantities measured as above shall be paid at the unit rates entered in the Bill of Quantities. Such payment shall be the full and the final compensation to the Contractor for executing all the works as specified in these Specifications.

(6) Pesticides for planting and maintenance

(a) The contractor shall provide required pesticides for planting and maintenance of sapling to protect from damage. Proper use, storage and disposal of pesticides should be carried out under the guidance of engineer or as per plant quarantine and pesticides management center, ministry of agriculture and livestock development.

(b) Only registered pesticides should be used to avoid health risk of human and other living things. List of banned pesticides with date of banned should be provided under the cost of contractor.

(c) Well trained manpower should be hired to use, storage and disposal of pesticides in proper way. Ration of water and pesticide should be calculated before use to avoid damage of plants due to excess quantity of pesticide.

(d) Safety gloves, mask, footwear and eye protection should be provided to the trained manpower.

1706 FINAL SLOPE PREPARATION FOR BIO-ENGINEERING

(a) The Contractor shall prepare slopes for planting operations as required by the engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.

(b) In the course of all slope preparation works, it shall be essential that no damage is done to existing vegetation unless the Engineer's instruction specifically requires certain plants to be removed.

(c) The timing of bio-engineering operations shall be of the utmost importance. Activities such as planting and seed sowing shall be carried out within the critical few weeks when they will yield the desired results. All other operations shall be carried out in timely manner to permit this to happen. The contractor shall be responsible to keep works to the strict schedule required and under no circumstances to permit delays.

(d) As slope trimming business can be dangerous and risky to personnel, the Contractor shall be responsible to ensure the safety of his/her and Client's personnel while putting in the dangerous situation. It shall be essential to have the minimum of safety measures as listed below for a working gang of 10 people. The proportion of the safety harness shall be increased according to the requirements and labours employed on site.

(e) The Contractor shall provide all safety measures as listed in Table 17.4 for his/her workers who will be on site and Employer's personnel who will be supervising the work within the Contractor's working premises.

Table 17.4: Materials Required for Safety Measures

S.No.	Description	Quantity
1	Safety rope (mountaineering type or similar make having a min 20 mm diameter and 30 meter in length.	For every worker
2	Safety belt similar to tree climbers or scaffolders use.	For every worker
3	Goggles and dust proof masks	For every worker
4	Safety hats	For every worker
5	Knee pad	For every worker
6	First aid kit with necessary medicines and bandages	1 box per working gang
7	Stretcher	1 no per working gang

(1) Cut Slope Preparation for Grass Planting

(a) The objective of final cut slope preparation shall be to produce a surface adequately prepared for grass planting. Grass lines shall be used to provide a strong surface cover. Grass lines shall be planted over a well prepared surface. The slope shall not be subject to any undue stress from erosion and mass movement in its initial stages.

(b) All the construction work shall be checked prior to slope trimming. The site shall be clear of people and equipment.

(c) Trimming shall be as follows:

New sites: trimming to straight plan section;

Retaining wall to be filled behind;

Old sites: minor trimming only required on part of site;

Keeping rill or gully pattern in plan section;

(d) The Contractor shall ensure that the slope under instruction is trimmed to a straight angle, according to the Engineer's instructions. Cut slopes to be planted with grass shall normally be 3 verticals: 2 horizontals, unless otherwise shown on the Drawing or instructed by the Engineer. In any event, a straight profile shall be obtained. Concavities shall be filled with well compacted material or dry stone dentition as instructed by the Engineer. Convexities shall be removed and it shall be ensured that the general profile does not have a shape giving over- steep segments

(e) All loose material shall be removed from the slope and tipped elsewhere in an approved location.

(f) Measurement and Payment: Work shall be measured in square meters on the basis of actual area of trimmed surface. The payment shall be the full and the final compensation to the contractor for making arrangements for diversion of water flows, drainage of slope seepage, care of water, and safety of workers, trimming, removal of loose materials, all labour, tools equipment, safety harness and incidentals to complete the work as specified herein.

(2) Final Preparation of Fill Slopes for Bio- Engineering

(a) The objective of the final preparation of fill slopes shall be to produce a surface adequately prepared for shrub or tree planting or grass sowing, or a combination of these. Vegetation shall be used to provide a strong surface cover. Vegetation shall be planted over a well prepared surface. The slope shall not be subject to any undue stress from erosion and mass movement in its initial stages.

(b) The Contractor shall ensure that the slope under instruction is trimmed to a straight angle, according to the Drawing or instruction of the Engineer. In any event, a straight profile shall be obtained. All masses of loose debris, especially where it has previously been tipped at the head of the slope, shall be removed. Concavities shall be filled with well compacted material or dry stone dentition as shown on the Drawing or instructed by the Engineer. Convexities shall also be removed, and it shall be ensured that the general profile does not have a shape giving over-steep segments.

(c) All loose material shall be removed from the slope and tipped elsewhere in an approved location.

(d) Measurement and Payment: The work shall be measured in square meters on the basis of actual area of trimmed surface as shown on the Drawing or instructed and approved by the Engineer. The quantities measured shall be paid at the unit rates shown in the Bill of Quantities. Such payment shall be the full and the final compensation to the Contractor for making arrangements for, diversion of water flows, drainage of slope seepage, care of water, and safety of workers on water-facing embankments, trimming, and removal of loose materials, all labour, tools, equipment, safety harness and incidentals to complete the work as specified herein.

1707 SITE PLANTING AND SOWING

(a) The Contractor shall plant or sow grasses, shrubs and trees as shown on the Drawing or required by the Engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.

(b) Due to the nature of bio-engineering works, they may also be undertaken by small local contractors with a range of agricultural skills, if so provided in the Contract. If provided in the Contract, any bio-engineering site activity may also be managed by direct employees of the Irrigation & Water Resources Management Projects.

(c) It shall be the Contractor's responsibility to ensure that all planting stock, whether provided from a nursery under a separate contract or through a separate instruction, is of high quality and is vigorous enough to grow on the site to be planted.

(d) All seeds and other planting stock shall be of species indigenous to Nepal unless otherwise specified. All species shall be covered in the current approved lists of species produced from time to time by the Environment & Disaster Management Section of the Department of Water Resources and Irrigation (DWRI). They shall be appropriate for the precise site conditions in which they are to be planted and the Contractor shall ensure that they apply to the specific altitude and other environmental characteristics of the site in question.

(e) Activities such as planting and seed sowing shall be carried out within the critical few weeks when they will yield the desired results. All other operations shall be carried out in a timely manner to permit this to happen. The Contractor shall be responsible to keep works to the strict schedule required and

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under no circumstances to permit delays.

(1) Sowing of Grasses on Site

(a) The Contractor shall be required to carry out the sowing of grass seeds according to the Engineer's specific instructions.

(b) If the site for sowing is to be prepared under a separate contract, then it shall be assumed that the site will already have been prepared for seed sowing. Nevertheless, it shall be the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of grasses.

(c) The Contractor shall be required to supervise all field operations very closely. The sowing of grass seeds is a delicate business and shall be approached in the same way as for agricultural crops. The Contractor shall employ experienced agricultural laborers for this work.

(d) If seeds have to be provided under a separate contract, then they shall be properly stored. However, it shall be the Contractor's responsibility to check that it has been carefully stored and remains fully viable.

(e) Immediately before sowing, the ground surface shall be lightly scarified using a rake to ease early root penetration. Seeds shall then be laid thinly over the surface. Under no circumstances shall they be broadcast, because the lightness of perennial grass seeds and the steepness of the slopes to be treated give a poor cover using such a technique. The Contractor shall be responsible for ensuring that the correct quantities of seeds are used, while giving a good, even cover.

(f) A cover of 25 grams of grass seed per square meter of surface shall be achieved unless otherwise specified.

(g) After sowing, a mulch of prepared and dried cut herbs shall be laid over the whole seeded area in a thin layer. If the mulch is too thick it will prevent light from getting to the seed and will inhibit germination. Herbs suitable for this and locally available in large quantities are:

- Tite pate (Artemisia vulgans);
- Tapre (Cassia species);
- Ban mara (Eupatorium adenophorum).

However, freshly cut herbs shall not be used because of the danger of resprouting and weeding.

(h) If specified, the mulch should be secured with jute netting of mesh size 300x 500 mm and the netting fixed in place using suitable live pegs or hardwood cuttings (e.g. Simali, Vitexnegundo) at one meter centers.

(i) Measurement and Payment: Work shall be measured in square meters on the basis of actual area of grass seeded and covered surface. The payment shall be the full and the final compensation to the Contractor for making arrangements for diversion of water flows, drainage of slope seepage, care of water, and safety of workers on water-facing embankments, providing seeds, collection and application of mulch, all labour, tools, equipment, safety harness and incidentals to complete the work as specified herein. If the seeds and mulch are supplied through a separate contract, costs for the supply of the same shall not be included herein. However, if the Contractor is responsible for the supply and storage of seeds and mulch no separate payment shall be made for these items.

(2) Direct Seed Sowing of Shrubs and Trees on Site

(a) The Contractor shall be required to carry out the sowing of shrub and tree seeds according to the Engineer's specific instructions.

(b) It is assumed that the site will already have been prepared for seed sowing, if this item has to be executed under a separate contract. Nevertheless, it shall be the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of shrubs and

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trees.

(c) The Contractor shall be required to supervise all field operations very closely.

(d) As the sowing of seeds is a delicate business and, therefore, shall be approached in the same way as for agricultural crops. The Contractor shall employ experienced agricultural laborers for this work.

(e) Seed shall have been collected and stored well before the time of sowing, if they have to be supplied under a separate contract. However, it shall be the Contractor's responsibility to check that it has been carefully stored and remains fully viable.

(f) Sowing shall start at the top of the slope, and the laborers shall work downwards. Care shall be taken not to disturb areas already seeded.

(g) To sow the seeds, a small hole shall be made in the slope. The tool used to do this shall depend on the size of the seed. For some seeds, a piece of gabion wire will be adequate; for others, a piece of mild steel with a flattened end is required. The hole shall be in the best soil available but if there is little real soil, then a crevice between two stones is acceptable. Two seeds should be placed in each hole and a covering of soil or whatever fines are available shall be placed over them. This covering shall never exceed 10 mm and shall preferably be about 5 mm; it shall never be less than and this. Seeds shall be placed at 200 to 250 mm centers, as ground conditions dictate.

(h) In some cases, the seed can be broadcast starting at the top of the site and working down slope as evenly as possible so that the whole site is lightly covered. This shall be used where the site is still active and only warrants minimum expenditure, or where the site is naturally rough, providing plenty of niches in which the seed can catch. Quantities of seed shall depend on the type of seed involved but are generally half that of the quantities used in the nursery unless otherwise instructed by the Engineer. With utis (Alnusnepalensis) seed it shall be at a rate of 1 gram of seed per square meter.

(i) Measurement and Payment: Work shall be measured in square meters on the basis of actual area of grass seeded and covered surface. The payment shall be the full and the final compensation to the Contractor for making arrangements for diversion of water flows, drainage of slope and safety of workers, providing seeds, collection and application of mulch, all labour, tools, equipment, safety harness and incidentals to complete the work as specified herein. If the seeds and mulch are supplied through a separate contract, costs for the supply of the same shall not be included herein. However, if the Contractor is responsible for the supply and storage of seeds and mulch no separate payment shall be made for these items.

(3) Site Planting of Grass Slips and Cuttings

(a) The Contractor shall be required to carry out the planting of grass seedlings or rooted the cuttings, according to the Engineer's specific instructions. The configuration of planting shall be determined according to individual site conditions. It shall be either random, contoured or downslope, as instructed by the Engineer.

(b) It is assumed that the site shall already have been prepared for planting, if this is to be prepared under a separate contract. Nevertheless, it shall be the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of grasses, and accords with the specifications given in Clause 1706.

(c) Using appropriate tools (such as tape measures and spirit levels), planting lines shall be marked out with string as required. Unless specified differently, the row spacing to be marked out shall be as shown in Table 17.5.

(d) The Contractor shall be required to supervise all field operations very closely. Since the planting of grass slips is a delicate business and therefore shall be approached in the same way as the transplanting of millet seedlings. The Contractor shall employ the experienced agricultural labourers for this work.

Table 17.5: Row Spacing Details

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Planting configuration	Slope steepness	Spacing
Random lines	All slopes	100 mm planting drill to drill
Contour lines	Slopes less than 35°	100 mm planting drill to drill and 1000 mm between the lines
	Slopes 35° - 45°	100 mm planting drill to drill and 500 mm between the lines
	Slopes more than 45°	100 mm planting drill to drill and 300 mm between the lines
Diagonal	Slopes less than 35°	100 mm planting drill to drill and 500 mm between the lines
	Slopes more than 35°	100 mm planting drill to drill and 300 mm between the lines
Downslope lines	All slopes	100 mm planting drill to drill and 300 mm between the lines

(e) The plants supplied to the Contractor from nursery (if so provided in the Contract) shall be prepared for planting by the Contractor as given below. The Contractor shall transport them from the nursery wrapped in hessian jute. At all times, plants shall be kept moist and as cool as possible, and should be wrapped in wet hessian between all operations such as extraction from the bed, pruning and planting. Under any circumstances, all plants supplied shall be planted within two days of that they are lifted from the nursery.

(f) Grass slips or cutting shall be carefully separated from the clumps to give the maximum viable planting material. Preparation of slips, cuttings or rhizomes shall be strictly followed as mentioned in Sub-clause 1703 (1).

(g) Planting shall be started at the top of the slope and under no circumstances shall new plants be walked on or otherwise disturbed. Using a small bar (usually made of mild steel and with a flattened end), a hole shall be made that is just big enough for the roots. The slip or cutting is inserted; care shall be taken that the roots are not tangled or bent back to the surface. Soil shall then be replaced around the roots and firmed with the fingers. The spacing of plants within rows shall be 100 mm unless otherwise specified. Two grass slips shall be planted in each drill.

(h) If the soil is dry and there is no rain within 16 to 24 hours of planting, the site shall be watered carefully with a fine spray. The Contractor shall be required to water for the first two weeks after planting in the event of inadequate rainfall.

(i) If it provided in the Contract that the plants are to be collected from locations other than nurseries then utmost care shall be taken to minimize disruption to neighboring land, in the event that species are collected from areas surrounding the road. It shall be the Contractor's responsibility to collect the stock required from a wide area and not to give rise to any soil erosion through the excessive removal of plants in one locality.

(j) Measurement and Payment: The measurement shall be the actual area of grass planted and covered surface in square meters for the random planting and any other patterns of planting up to the 300 mm between the lines. The contour line planting in 500-1000 mm in any slopes shall be measured in linear meter. The payment shall be the full and final compensation to the Contractor for making arrangements for diversion of water flows, drainage of slope seepage, care of water, and safety of workers, providing grass slips or rhizome, collection of mulch, all labour, tools, equipment, safety harness and incidentals to complete the work as per these Specifications. If the grass slips and mulch are supplied through a separate contract, costs for the supply of the same shall not be included herein. However, if the Contractor is responsible for the supply slips and mulch, no separate payment shall be made for these items.

(4) Site Planting of Shrubs, Trees raised in Polythene Pots and hedge plant

(a) The planting of trees and shrubs is intended to replace or restore something of the natural vegetation on the slope to be treated. The Contractor shall be required to carry out the planting of seedlings to

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the Engineer's specific instructions.

(b) Planting hedge plant spacing 30 cm apart for erosion control and slope stabilization. Watering should be done in time during sapling phase of plant.

(c) It is assumed that the site will already have been prepared for planting if it has to be prepared under a separate contract. Nevertheless, it shall be the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of delicate young plants.

(d) The spacing of plants shall be determined according to individual site conditions. However, it shall normally be at 1.5 meters' interval unless otherwise specified or instructed by the Engineer.

(e) The Contractor shall be required to supervise all field operations very closely. As the planting of trees and shrubs is a delicate business and should be approached in the same way as the planting of horticultural seedlings. The Contractor shall employ experienced agricultural or forestry labourers for this work.

(f) If the plants are to be supplied to the Contractor from a nursery under a separate contract, they will be ready for planting. They shall be at least 300 mm in height above the soil surface and hardened off in the normal way. The Contractor shall collect the plants from the nursery and transport them to site with all due care.

(g) The plants will normally be supplied in polythene pots, which shall not be removed until the moment of planting. Plants shall be lifted by the pots, never by the stem or leaves. At all times they are to be kept as cool as possible. The Contractor shall be responsible for ensuring that the soil around the roots does not dry out. Under any circumstances, all plants supplied must be planted within three days of removal from the nursery.

If it is provided in the Contract that the Contractor is responsible for the supply of land, plants, he shall maintain the same workmanship and standard as specified herein.

(h) Planting shall be started at the top of the slope and under no circumstances shall new plants be walked on or otherwise disturbed.

(i) A planting pit wide and deep enough for the main root to be buried in without bending it and wide enough for all the roots and surrounding soil ball shall be made at the time of planting. Some compost if available shall be mixed with the soil from the slit prior to backfilling around the roots. The polythene pot must be removed from the seedling by cutting it away with a razor blade. The plant should then be carefully placed into the hole, the compost and soil packed in, and all surrounding soil firmed up, taking care not to cause any damage to the plant or its roots. The surface over and around the pit shall then be mulched using any appropriate, locally available material, such as manure, compost, dead leaves or cut herbage. The use of freshly cut ban mara (Eupatorium adenophorum) shall be avoided, since it can resprout from the buds after being cut.

(j) The Engineer may specify bigger seedlings for specific areas, such as those to be used intensively for amenity purposes. These will normally have been growing in a nursery for at least a year and should have well developed roots as well as aerial parts. They will be provided either as bare root stock with a substantial root ball, or in pots of a minimum of 100 x 180 mm laid flat dimensions. When these larger seedlings are planted, the pits shall be of 300 mm diameter and 300 mm depth. In addition, well-rotted compost shall be mixed with the soil backfill in a ratio of at least one-part compost to ten parts soil.

(k) Measurement and Payment: The measurement shall be made in number of seedlings planted, counted and accepted by the Engineer at site. The quantities measured shall be paid at the unit rates shown in the Bill of Quantities. This payment shall be the full and the final compensation to the Contractor for making arrangements for diversion of water flows, drainage of slope seepage, care of water, and safety of workers, providing seedlings, collection and application of mulch, all labour, tools, equipment, safety harness and incidentals to complete the work as per these Specifications.

If the seedlings and mulch are supplied through a separate contract, costs for the supply of the same shall not be included herein. However, if the Contractor is responsible for the supply seedlings and mulch, no separate payment shall be made for these items.

(5) Site Planting of Hardwood Cutting

(a) Certain trees and shrubs can be planted on site by means of hard wood cuttings. Where these are specified, the Contractor shall be required to carry out the planting of cuttings as required in the Engineer's instructions.

(b) It is assumed that the site will already have been prepared for planting, if it is to be prepared under a separate contract. Nevertheless, it shall be the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of delicate young plants.

(c) The spacing of hardwood cutting shall be determined according to individual site conditions. However, it will normally be at 500 mm centers unless otherwise specified.

(d) The Contractor shall be required to supervise all field operations very closely. The planting of tree and shrub cuttings is a delicate business and shall be approached in the same way as the planting of horticultural cuttings (e.g. those of tea). The Contractor shall employ experienced agricultural or forestry laborers for this work.

(e) The cuttings supplied to the Contractor will normally be from a nursery as arranged by separate instructions, and will be ready for planting. If these cuttings are to be provided by the Contractor himself, he shall make such arrangements so as to make the cuttings ready for planting. The size of the cuttings shall be prepared as specified in Sub-clause 1703 (2) unless otherwise instructed by the Engineer. The Contractor shall collect the cuttings from the nursery (if provided in the Contract) and transport them from the nursery wrapped in hessian jute. At all times, cuttings shall be kept moist and as cool as possible, and shall be wrapped in wet hessian between all operations such as cutting from the parent plant, trimming and planting. Under any circumstances, all plants supplied shall be planted the same day that they are lifted from the nursery.

(f) Planting shall be started at the top of the slope and under no circumstances shall new plants be walked on or otherwise disturbed. Using a small bar (usually made of mild steel and with a pointed end), a hole shall be made that is just big enough for the cutting. The cutting shall be inserted and the soil shall be replaced around it and firmed with the fingers. The cutting shall be inserted to depth such that two-thirds to three-quarters of it is buried.

(g) If the soil is dry and there is no rain within 16 to 24 hours of planting, the site shall be watered carefully with a fine spray. The Contractor shall be required to water for the first two weeks after planting in the event of inadequate rainfall.

(h) If it is provided in the Contract that the cuttings to be used are to be from elsewhere other than nurseries, then the Contractor shall obtain them in the manner described in Sub-clause 1703 (2).

(i) The Engineer may specify bigger cuttings for specific areas, using large truncheon cuttings. In this category fall chuletro (Brassaiopsishainla), dabdabe (Garugapinnata), kavro (Ficuslacory, phaledo (Erythrina species), ghurbis (Leucosceptrumcanum) and Gliricidiasepium. Cuttings of these species should planted at 1000 mm centres burring up to 500 mm. A large crowbar shall be used to make the planting hole, but otherwise the technique shall be as described above for smaller cuttings. Under no circumstances shall these cuttings be hammered into the ground.

(j) Measurement and Payment: The measurement shall be made on the basis of per number of cuttings planted, counted and accepted on site by the Engineer. The quantities measured shall be paid at the unit rates shown in the Bill of Quantities. This payment shall be the full and final compensation to the Contractor for making arrangements for diversion of water flows, drainage of slope seepage, care of water, and safety of workers, providing and delivering seedlings, all labour, tools, equipment, safety harness and incidentals to complete the work as per these Specifications. If the seedlings are

supplied through a separate contract, costs for the supply of the same shall not be included herein. However, if the Contractor is responsible for the supply seedlings, no separate payment shall be made for this item.

(6) Brush Layering, Palisades and Fascines

(a) Under certain conditions, the Contractor shall be required to construct vegetation structures using hardwood cuttings. Where these are specified, the Contractor shall be required to carry out the necessary preparation and planting works as required in the Engineer's instructions.

(b) It is assumed that the site will already have been prepared for planting, if it has to be prepared under a separate contract. Nevertheless, it shall be the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of delicate young plants.

(c) The cuttings supplied to the Contractor may be from a nursery as arranged under a separate contract and will be ready for planting. If the cuttings have to be arranged by the Contractor, he shall ensure that they are ready for planting. The cuttings shall be prepared as specified in Sub-clause 1703 (2) or as instructed by the Engineer. The Contractor shall collect the cuttings from the nursery and transport them from the nursery wrapped in hessian jute. At all times, cuttings shall be kept moist and as cool as possible and shall be wrapped in wet hessian or in the thick blanket of mulch material (i.e. as titepati and ban mara) between all operations such as cutting from the parent plant, trimming and planting. Under any circumstances, all plants supplied shall be planted the same day that they are lifted from the nursery.

(d) If the instruction to the Contractor includes the provision of cuttings, then the Engineer shall specify the species and expected sources, and the Contractor must then obtain the cuttings required. This shall be done in the manner described in Sub-clause 1703 (2) except that the size of cuttings will be of a minimum length of 450-600 mm for brush layering, 600 mm for palisades and 1000 mm for fascines, and minimum diameters of 20-30 mm for brush layering and palisades and 40-50 mm for fascines.

(e) Cuttings of the following species, if specified for the truncheon cuttings planting, shall be a minimum of 2500-3000 mm in length: chuletro (Brassaiopsishainla), dabdabe (Garugapinnata), kavro (Ficuslacory, phaledo (Erythrina species), ghurbis (Leucosceptrumcanum) and Gliricidiasepium.

(f) The Contractor shall be required to supervise all field operations very closely. The planting of tree and shrub cuttings is a delicate business and shall be approached in the same way as the planting of horticultural cuttings (e.g. those of tea). The Contractor shall employ experienced agricultural or forestry laborers for this work.

(g) Planting shall always be started at the top of the slope and under no circumstances shall new plants be walked on or otherwise disturbed.

(h) Brush layering on embankment slopes shall be planted as given below, unless specified differently.

(i) Starting at the top of the area to be treated, and using appropriate measuring equipment, exact lines should be marked out. From 0.50 m to 1.0 m below the embankment crest / canal inspection road shoulder, stepping down toward the riverside or canal water line.

(ii) After the line marking is completed, starting at the bottom of slope, a back sloped terrace (1: 10) of approximately 300 mm in width x 100 mm inner depth and 300-400 mm outer depth should be excavated along the lines. The terrace must not be allowed to open more than 5 metres length at time before planting work is completed.

(ii) Topsoil or agricultural soil of maximum depth of 100 mm from the ROW should be collected and laid on the terrace. The minimum thickness shall be 50 mm unless otherwise instructed by the Engineer.

(iii) Cuttings should then be placed into the terrace at 100 mm centres, the correct way up and angled so that they are at right angles to the maximum slope angle. All cuttings should be

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inserted to a depth such that two-thirds of their length is buried.

(iv) The terrace should then be partially backfilled with another 50 mm thick layer of topsoil and another line of cuttings placed (pushing into the soil) along the terrace at 100 mm centres, and with the individual cuttings offset to coincide with the gaps between the cuttings in the first line. This results in cuttings at 50 mm final gap on each brush layer (i.e. 21 cuttings per linear metre).

(v) When a practical working length is completed, formation of second terrace is then started. As the excavation is undergoing, the partially backfilled brush layering terrace below should be fully backfilled using the material that comes out of the second terrace and gently compacted. Any loose or excess material is cleared down the slope making the complete daylight upon the completion of whole slope.

(i) Brush layering on the landslide debris shall be planted as given below, unless specified differently.

(i) Starting at the bottom of the area to be treated, and using appropriate measuring equipment, exact lines shall be marked following a precise contour line at 1 meter interval.

(ii) After the line marking is completed, starting at the bottom of slope, a back sloped terrace (1: 1 0) of approximately 450 mm in width x 100 mm inner depth and 300-400 mm outer depth shall be excavated along the lines. The terrace shall not be allowed to open more than 5 metres length at time before planting work is completed.

(iii) Cuttings shall then be placed into the terrace at 100 mm centres, the correct way up and angled so that they are at right angles to the maximum slope angle. All cuttings shall be inserted to a depth such that two-thirds of their length is buried. The terrace shall then be partially backfilled with 50 mm layer of soil and another line of cuttings placed (pushing into the soil) along the terrace at 100 mm centres, and with the individual cuttings offset to coincide with the gaps between the cuttings in the first line. This results in cuttings at 50 mm final gaps on each brush layer (i.e. 21 cuttings per linear metre).

(iv) When a practical working length is completed, formation of second terrace shall then be started. As the excavation is undergoing, the partially backfilled brush layering terrace below shall be fully backfilled using that material coming out of the second terrace and gently compacted. Any loose or excess material shall be cleared down the slope making the complete daylight upon the completion of whole slope.

(v) Brush layering is often done in diagonal or chevron pattern. If it is instructed so, the procedure given above shall be followed accept setting out lines, which shall be changed accordingly.

(j) Palisades shall be constructed as given below, unless specified differently.

(i) Starting at the top of the area to be treated, and using appropriate measuring equipment, exact lines shall be marked out. From 1 metre below the top of the slope, a precise contour line shall be marked out every 1 metre down the slope.

(ii) Starting at one end and using a small bar (usually made of mild steel and with a pointed end), a hole shall be made that is just big enough for the first cutting. The cutting shall be inserted and the soil shall be replaced around it and firmed with the fingers. The cutting shall be the correct way up and angled so that it is vertical. The cutting shall be inserted to a depth such that two-thirds of it is buried.

(iii) This process shall be repeated along the entire line, with a series of cuttings placed at 50 mm centers.

(iv) If a double line is specified, then a second line of cuttings shall be placed in the same way, 100 mm behind the first and with the individual cuttings offset to coincide with the gaps between the cuttings in the first line.

(v) The soil around the single or double line shall then be completely backfilled into any remaining gaps and gently compacted. Any loose or excess material shall be cleared down the slope before the next line is planted.

(k) Fascines shall be bundles of hardwood cuttings laid horizontally in trenches, and parallel to the line of the trench. The bundles shall be thereby completely buried. Fascines shall be constructed as given below, unless specified differently.

(i) Starting at the top of the area to be treated, and using appropriate measuring equipment, exact lines shall be marked out. From 1 metre below the top of the slope, a precise contour line shall be marked out every 1 metre down the slope.

(ii) Starting at the bottom as the marking is completed, trenches approximately 200 mm x 200 mm in depth shall be excavated along the lines.

(iii) 600 mm long cuttings of same material that is going to make fascine shall be planted on the lower side of trench in vertical position as a peg at 1000 mm interval.

(iv) Cuttings shall then be laid along each trench, so that they lie horizontally along the trench. There shall be a minimum of six cuttings together. They shall be overlapped so that no two ends coincide. All the small branches growing from the main branch shall be protruding on slope. Under no circumstances, the branches and buds shall be damaged. The cuttings shall then be tied using jute or coir (coconut fibre) string at 500 mm intervals to form a bundle. As the fascine is created, it thereby forms a continuous bundle right across the slope.

(v) The trench shall then be backfilled and gently compacted. The top of the fascine shall be 50 to 100 mm below the surface. Any loose or excess material shall be cleared down the slope before the next line is planted.

(vi) The Engineer may specify that orientations other than along the contour of the slope are used. In this event, the Contractor shall alter the laying out of lines accordingly and meet the precise angle required.

(vii) If the soil is dry and there is no rain within 16 to 24 hours of planting, the site shall be watered carefully with a fine spray. The Contractor shall be required to water for the first two weeks after planting in the event of inadequate rainfall.

(l) Measurement and Payment: Brush layering, Palisades and Fascines shall be measured separately as per the accepted final product in linear meter. The payment shall be the full and final compensation to the Contractor for making arrangements for diversion of water flows, drainage of slope seepage, care of water, and safety of workers collecting and transporting of cuttings to the site, all labour, tools, equipment, safety harnesses and incidentals to complete the work as per these Specifications. If the cuttings are supplied through a separate contract, costs for the supply of the same shall not be included herein. However, if the Contractor is responsible for the supply cuttings, no separate payment shall be made for this item.

(7) Use of Fertilizer

(a) Under certain circumstances, the use of chemical fertilizers (chemical manure) may be specified in place of farmyard manure or mulching.

(b) Levels of fertilizer application shall vary according to soil type and nutritional content. However, if nutritional data are not available, the following figures shall be used as a rough guide:

Nitrogen (N): 10 g/m2;

Phosphorus (P). 5 g/m2;

Potassium (K). 4 g/m2.

Table 17.6 below lists the chemical composition and percentage of the major plant nutrient elements in the

chemical fertilizers (chemical manure) commonly available in Nepal.

Table 17.6: Chemical Composition of Major Plant Nutrient Elements

Chemical name	Chemical formula	Percentage (N) (P) (K)		
Sulphate of ammonia	(NH4)2SO4	21	0	0
Urea	CO(NH4)2	46	0	0
Triple superphosphate	CaH(PO4)	0	21	0
Muriate of potash	KCL	0	0	49
Complexol	Unknown	20	20	0
Diammonium phosphate	(NH4)2HPO4	18	20	0

1708 JUTE NETTING WORKS

(a) The Contractor shall provide and install jute netting as shown on the Drawing or as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.

(b) The Engineer may instruct that jute jetting applications be used in conjunction with other or the techniques, particularly the sowing or planting of grasses. In this event, the netting shall be applied before the plants are introduced. When planting, the laborers shall take care only to hold or stand on the wooden pegs and not to disturb the netting except when carefully placing grass seed underneath on the soil surface.

(1) Supply of Jute Netting

(a) The Contractor shall manufacture or obtain a supply of jute netting to the Engineer's specification.

(b) The detailed specifications for standard jute netting (Open weave 2 .5 cm) shall be as follows. "Standard" jute netting is used for placing on bare slopes and is normally planted with grasses. (Note: warp ends are the length-ways threads and weft strands are the cross-ways threads)

i.	Material:	High quality, 100% natural jute fibre from the latest harvest, properly treated and dried
ii.	Yarn:	Handspun 5 to 8 mm.
iii.	Strip size:	Minimum 1.0 x 10.0 metres;
		Maximum 1.1 x 11.5 metres.
iv.	Warp Ends	27 ends per 1000 mm.
v.	Weft trands:	20 to 24 strands per 1000 mm.
vi.	Mesh size:	40 mm square mesh holes.
vii.	Weight:	1.1 to 1.2 kg per square meter.

(c) The detailed specifications for wide mesh jute netting shall be as follows. "Wide mesh" jute netting is used for holding much on to slopes which have been sown with grass seed, (Note: warp ends are the length-ways threads and weft strands are the cross-ways threads)

(i) Material: High quality, 100% natural jute fiber from the latest harvest,

(ii) Properly treated and dried.

(iii) Yarn: Handspun 3 to 5 mm.

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(iv) Strip size: minimum 1.0 x 5.0 metres, maximum 1.1 x 11.5 metres.

(v) Warp ends: 7 ends per 1000 mm.

(vi) Weft strands: 3 strands per 1000 mm.

(vii) Mesh size: 150 x 450 mm rectangular mesh.

(viii) Weight: 0.2 kg per square meter.

(d) Measurement and Payment: No separate measurement and payment shall be made for the supply of jute netting. All costs incurred for the supply of jute netting shall be included in the item rate for the placement of jute netting.

(1) Placement of Small Mesh Size Jute Netting/Standard Jute Netting

(a) The Engineer shall normally instruct the placement of standard jute netting on slopes in excess of 45°. It is therefore very essential to place the netting in an effective manner which fulfils the Engineer's purpose.

(b) It is assumed that the site will already have been prepared for the application of jute netting, if it is to be prepared under a separate contract. Nevertheless, it shall be the responsibility of the Contractor to ensure that the condition of the site is good enough for the optimum effect to be attained. In any event, a smooth profile must be obtained. All loose debris shall be removed. Concavities shall be filled with well compacted material or dry stone dentition as shown on the Drawing or as instructed by the Engineer. Convexities shall also be removed and it is essential that the general profile does not have a shape giving over-steep segments.

(c) Starting at one end of top of the site to be treated, a roll of netting shall be pegged 300 mm above the slope to be covered.

(d) The netting shall be rolled slowly down the slope. Hardwood cuttings, ideally of simali (Vitexnegundo) or pegs (usually made from split bamboo culms) shall be hammered through the netting at 1000 mm centres at 100 mm inside of each edges. They shall protrude about 80 mm on the slope. Labourers shall stand on these cuttings or pegs and not hang on to the netting. As the full length of the jute netting is unrolled down the slope, a second round of the pegs shall be added in between. This will make total allowable spacing of not more than 500 mm interval. Another strip shall then be started to unroll from the top. This shall overlap by 100 mm and under no circumstances the pegging is done through the both layer of jute net instead it shall be pegged separately. Each strip of jute netting shall be pegged down on the slope individually.

(e) The tension of the netting shall now be reduced so that it hugs the slope surface precisely. This is done by pulling up about 200 mm at the bottom of the netting and hooking it on to the pegs a little higher up. This process shall be repeated up and across the slope until the netting rests snugly against the surface and is nowhere tight or pulled away from the surface in minor concavities. Additional wooden pegs shall be used to hold netting closely against the face of concave slope segments if necessary.

(f) This process shall be repeated until the entire slope surface is covered. There shall be no lacing of any jute netting whatsoever.

(g) Finally, the bottom of the netting shall be trimmed to give a tidy finish

(h) Measurement and Payment: As the actual quantity of jute net and area covered on slope differ from each other due to the overlapping, payment shall be made on the basis of final area covered on slope and measured in square meter (not the Quantity of jute net). The payment shall be the full and the final compensation to the Contractor for making

arrangements for diversion of water flows, drainage of slope seepage, care of water, and safety of workers, purchasing of jute, arrangement for looms and shades, fabrication of jute netting and transportation to the site, all labour, tools, equipment, safety harnesses and incidentals to complete the work as per these Specifications.

(2) Placement of Wide Mesh Size Jute Netting

(a) In the case of wide mesh jute netting, it shall only be specified for use on slopes which have already been treated with grass and mulch. These shall usually be less than 45°. However, the process of placing the netting shall be similar to that for standard netting.

(b) Unlike the standard mesh jute net, wide mesh jute net is available on shorter length of 5.5 metres and smaller roll in nature. It shall be opened by two people by two end laid flat (same as bed sheet is laid) on seeded and mulched slope.

(c) The netting shall be pegged with hardwood cuttings, ideally of simali (Vitexnegundo) or pegs (usually made from split bamboo culms) at every 500 mm intervals. The Contractor shall ensure that his/her labourers do not damages the area of seeding and mulching while placing the jute net.

(d) This process shall be repeated until the entire slope surface is covered. The strips shall then have laced together with lengths of the same jute yarn, to form a continuous net. The lacing shall form joins every 500 mm or less.

(e) The tension of the netting shall now be reduced so that it hugs the slope precisely and hold the mulch firmly against the surface throughout the area covered. Additional pegs shall be used to hold netting closely against the face of concave slope segments.

(f) Finally, the bottom of the netting shall be trimmed to give a tidy finish.

(g) Measurement and Payment: The payment shall be made on the basis of final area covered on slope and measured in square meter (not the quantity of jute net). The payment shall be the full and the final compensation to the Contractor for making arrangements for diversion of water flows, drainage of slope seepage, care of water, and safety of workers, purchasing and transporting of jute net to the site, all labour, tools, equipment, safety harnesses and incidentals to complete the work as per these Specifications.

1709 GABION WIRE BOLSTERS

The contractor shall provide and install gabion wire bolsters as shown on the Drawing or instructed by the Engineer. This shall be done according to the specifications described hereunder, as when required.

The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.

(1) Fabrication of Bolster Panels

(a) Bolster panels shall be either 5 x 1 metres or 5 x 2 metres in size, according to the type of bolster to be used. They shall be woven with hexagonal mesh in the same way as normal gabion panels. For the panel frame, 10 gauge SWG galvanized wire shall be used; for the mesh, 12 SWG shall be adequate. Gabion wire shall comply with the requirements of Section 1500.

(b) Weaving shall start from one of the long sides. A total of 71 coils of wire shall be spaced evenly along the 5 meter length. This gives a mesh width of about 70 mm. Each weave shall have three twists, as for normal hexagonal mesh. This shall give a length of about 90 mm to each mesh link. In any event, the mesh length shall not exceed 100 mm. The mesh shall be turned on to the larger frame wire at least one and a half turns and made fully secure.

(2) Placement of Contour Bolsters

(a) A contour bolster treatment shall give a series of stone-filled wire tubes of 300 mm diameter, laid in trenches cut across the slope. The tops of all the tubes shall be flush with the surface of the slope in which they are placed. The purpose shall be to check scour of the slope surface by preventing the development of rills and gullies.

(b) The site to be treated shall be given final preparation immediately before bolster installation. All small protrusions and depressions shall be obliterated by cutting, or by infilling and compaction.

(c) Starting at the base of the area to be treated, and using appropriate measuring equipment, exact lines shall be marked out. From 2 metres above the base of the slope, a precise contour line shall be marked out every 2 metres up the slope.

(d) Starting at the bottom, trenches with circular base shall be dug along the lines, adequate to take the final 300 mm diameter tubes.

(e) Bolster panels shall then be laid along the trenches and shaped to fit neatly into the base of the trenches, as well as into any curves formed as a result of the slope contours; each panel shall be securely joined to the next panel, to form a continuous bolster tube.

(f) The panels shall be packed with stones, closed over and the edges wired together. All stones must be bigger than the mesh size. The same care shall be taken as when filling a conventional gabion basket, and stones must be carefully placed to give good structural integrity.

(g) The ends of the bolsters shall be closed over and wired together. The trenches around all the bolsters shall then be filled and compacted with material left from the excavations.

(h) Once all of the lines are in place, all surplus debris shall be cleaned off the slope. Mild steel bars of at least 12 mm diameter shall then be driven into the slope through lower sides of the contour bolsters. These shall be at least every 1 metre along the lines. Bars shall be 1-2 metres in length on slopes composed of soft materials, but at the Engineer's discretion, on slopes comprising hard rocky materials, bars of 1 meter length shall also be adequate. All bars shall be driven home until the tops protrude no more than 25 mm above the slope surface.

(3) Measurement and Payment:

(a) Bolster shall be measured as per the accepted final product in linear meter. Payment shall be made at contract unit rate as specified in BOQ of the contract. The Contract unit rate shall be the full and the final payment to the Contractor as per Clause 115. In addition to that stated in Clause 115, the contract unit rate shall be the full and the final compensation to the Contractor for making arrangements for diversion of water flows, drainage of slope seepage, care of water, and safety of workers, fabrication of bolster panel including cost of wire, collection and transportation of boulder/stone to the site, packing of stones/boulders, wiring, supply and driving of steel bars, excavation and filling, all labour, tools, equipment, safety harnesses and incidentals to complete the work as specified in these Specifications.

1710 SITE PROTECTION

(a) The Contractor shall protect a planted site for the period specified in the Contract. Protection shall include the prevention of damage to all manner of site works and plants by people and domestic or wild animals. It shall also include an active role in tending the plants and improving their growth, as specified below.

(b) The period of maintenance/site protection shall be twelve months unless otherwise specified in the Contract.

(1) Provision and Role of Watchman for maintenance

(a) Watchmen shall be required for the maintenance and protection of planting works (Trees and

permanent hedge) for at least one year. The Contractor shall be required to provide an adequate number of site watchman as per the provision for employment of watchmen to look after the site to fulfil the specified requirements. The function of watchman shall be intense as it shall involve a number of routine maintenance operations.

(b) Watchmen shall be mature and reliable characters who need little supervision for the adequate fulfilment of their duties. They shall be active and physically fit. Old people who are losing their strength shall not be employed. They shall be experienced agricultural workers familiar with caring for plants. They shall remain on site through all hours of daylight and through all adverse weather conditions. They shall eat their meals on site and at no time leave the site untended for any reason whatsoever.

(c) The role of the watchman shall be primarily to tend the plants. He/she shall take the initiative in weeding, mulching, replanting failed plants, pruning and protecting plants against all pests. This shall be an active role requiring individuals with considerable energy and initiative. The watchman shall work constantly to maintain and improve the site and its bio-engineering plants.

(d) The watchman shall also be required to protect plants on the site from damage by local people, domestic and wild animals. In doing this he/she shall use a friendly approach to the people as far as possible. The Contractor shall educate the watchman fully in the reasons for his/her job, so that he/she can communicate with others. He/she also shall have to fulfil an inevitable function as the ambassador between the Department of Water Resources and Irrigation and local irrigation neighbors.

(e) Measurement and Payment: Site watchman employed as per the provision under the Contract shall be paid separately as the respective item unit cost does not include the cost of the watchman. The cost of employment of watchmen shall include the execution of all works specified for maintenance. The measurement of watchmen employed for maintenance of planting works shall be in man-days and payment shall be made in unit contract rate specified in the contract.

(2) Fabrication of Bamboo Tree Guards

(a) The Contractor shall provide bamboo tree guards as shown on the Drawing or specified in the Contract. This shall be done according to the specification described hereunder, as and when required. The Contractor shall supply all necessary supervision, resources and facilities to ensure that these requirements are met.

(b) The bamboo strips used to make bamboo tree guards shall be made from mal bans (Bambusanutanssubspcupulata) whilst the uprights are to be made from tharu or dhanu bans (Bambusanutanssubspnutans or Bambusabalcooa). Bamboo tree guards shall be a minimum of 600 mm in diameter by 1300 mm in height so that they are able to provide sufficient protection from grazing and from the elements for the first 18 months after planting the seedling.

(c) The guard shall be made by cutting 5 bamboo posts which are a minimum of 50 mm wide by 10 mm thick and at least 1600 mm long. The posts shall be cut so that they have a strong spear-like point at the bottom that can be driven into the ground when placing out on site. The bamboo poles used to make the uprights shall be a minimum of 3 years old.

(d) Bamboo strips, a minimum of 5 mm thick and 50 mm wide shall be cut from poles that are at least 2 years old. The bamboo used shall be split so that the outer wall remains intact. Only lengths with the outer wall intact shall be used. The split bamboo shall be the length of the whole bamboo pole that it is cut from, or as long as possible. The split bamboo shall be woven in and out of the bamboo uprights and pulled tight, so that it is firm and strong. The end of each of the strips shall be woven back into the basket and tied with binding wire to keep it in place. End pieces shall not be left sticking out and unbound, because they quickly get broken and the basket starts to unravel from this point. The split bamboo shall be woven round the poles so that when they are tightly pressed down there are no gaps in the guard.

(e) Measurement and payment: Bamboo tree guard as specified in the contract or on the drawing shall be measured in number. Payment shall be made in contract unit rate specified in BOQ of the contract and it shall be the full compensation to the contractor as specified in clause 115.

(3) Placement of Bamboo Tree Guards

(a) Tree guards shall be installed on site at the time of planting, no later than the Second week of July, and shall be placed carefully around the planted seedlings.

(b) The tree guards shall be placed over the seedling immediately after planting. The Upright posts shall be firmly driven at least 300 mm into the ground so that the guard is able to resist bashing and rubbing from cows, buffaloes, goats and people. The woven slats shall be pushed down firmly from the bottom upwards so that they touch one another and are free from large gaps.

(c) Tree guards alone are not adequate protection for small plants. The Contractor shall provide a site Warden in addition, for the time specified, to maintain the tree guards and ensure that local people respect them, and generally fulfil all the requirements of Sub-clause 1710 (1).

(d) Measurement and Payment: No separate payment shall be made for the placement of the bamboo tree guards as its cost shall be deemed to be included in respective item rates in the contract.

(4) Bamboo Fencing

(a) Bamboo Fencing for the protection of plantation area shall be made with the use of bamboos, nails and 14 gauge SWG Wire.

(b) Measurement and Payment: Measurement of bamboo fencing as specified in the contract or on the drawing shall be made in running meter of the work executed. Payment shall be made in contract unit rate specified in BOQ of the contract and it shall be the full compensation to the contractor as specified in clause 115.

1711 TURFING WITH SODS

(1) General

This work shall consist of furnishing and laying of the live sod of perennial turf forming grass on embankment slopes, verges (earthen shoulders) or other locations shown on the drawings or as directed by the Engineer. Unless otherwise specified, the work shall be taken up as soon as possible following construction of the embankment, provided the season is favorable for establishment of the sod.

Besides turfing with sods and planting vetiver for slope protection, Slope erosion can be controlled by planting different type of grasses after spreading seeds on the exposed sloped surface and using chemical manure and watering.

(2) Materials

The sod shall consist of dense, well-rooted growth of permanent and desirable grasses, indigenous to die locality where it is to be used, and shall be practically free from weeds or other undesirable mailer. At the time the sod is cut, the grass on the sod shall have a length of approximately 50 mm and the sod shall have been freed of debris. Thickness of the sod shall be as uniform as possible, with some 50 - 80 mm or so of soil covering the grass roots depending on the nature of the sod, so that practically all the dense root system of the grasses is retained in the sod strip. The sods shall be cut in rectangular strips of uniform width, not less than about 250 mm x 300 mm in size but not so large that it is inconvenient to handle and transport these without damage. During wet weather, the sod shall be allowed to dry sufficiently to prevent rearing during handling and during dry weather shall be watered before lifting to ensure its vitality and prevent the dropping of the soil in handling.

(3) Construction Operations

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(a) Preparation of the earth bed:

The area to be sodded shall have been previously constructed to the required slope and cross section. Soil on the area shall be loosened, freed of all stones larger than 50 mm size, sticks, stump s and any undesirable foreign matter, and brought to a reasonably fine granular texture to a depth of not less than 25 mm for receiving the sod. Where required, topsoil shall be spread over the slopes. Prior to placing the topsoil, the slopes shall be scarified to a depth which, after settlement, will provide the required nominal depth shown on the plans. Spreading shall not be done when the ground is excessively wet. Following soil preparation and top soiling, where required, fertilizer and ground limestone when specified shall be spread uniformly at the rate indicated on the plans. After spreading, the materials are incorporated in the soil by discing or other means to the depths shown on the plans.

(b) Placing the sods:

The prepared sod bed shall be moistened to the loosened depth, if not already sufficiently moist, and the sod shall be placed thereon within approximately 24 hours after the same had been cut. Each sod strip shall be laid edge to edge and such that the joints caused by abutting ends are staggered. Every strip, after it is snugly placed against the strips already in position, shall be lightly lamped with suitable wooden or metal tampers so as to eliminate air pockets and to press it into the underlying soil. On side slopes steeper than 2 (horizontal) to 1 (vertical), the laying of sods shall be started from bottom upwards. At points where water may flow over a sodded area, the upper edges of the sod strips shall be turned into the soil below the adjacent area and a layer of earth placed over tins followed by its thorough compaction.

(c) Staking the sods:

Where the side slope is 2 (horizontal) to 1 (vertical) or steeper and the distance along the slope is more than 2 m, the sods shall be staked with pegs or nails (2.5” to 3”) spaced approximately 500 to 1000 mm along the longitudinal axis of the sod strips. Stakes shall be driven approximately plumb through the sods to be almost flush with them.

(d) Top dressing:

After the sods have been laid in position, the surface shall be cleaned of loose sod, excess soil and other foreign material. Thereafter, a thin layer of topsoil shall be scattered over the surface of top dressing and the area thoroughly moistened by sprinkling with water:

(e) Watering and maintenance:

The sods shall be watered by the Contractor for a period of at least four weeks after laying. Watering shall be so done as to avoid erosion and prevent damage to sodded areas by wheels of water tanks. The Contractor shall erect necessary warning signs and barriers, repair or replace sodded areas failing to show uniform growth of grass or damaged by his operations and shall otherwise maintain the sod at his cost until final acceptance,

(f) Measurements and Payment

The measurement turfing with sods shall be made as finished work in square metres, accepted on site by the Engineer. Payment shall be made at the contract unit rate specified in the BOQ of the contract and it shall be the full and final compensation to the contractor as specified in clause 115.

1712 NAPIER GRASS/VETIVER PLANTATION

(1) General

This work shall consist of furnishing and planting of the Napier Grass/Vetiver forming grass on embankment slopes, sloped land, or other locations shown on the drawings or as directed by the Engineer. It is effectively used for steep slope protection. Unless otherwise specified, the work shall be executed in wet/rainy season.



Vetiver for Slope Stabilization (Slope > 80°)

(2) Material

Vetiver/Napier is a special type of grass having longer and dense roots. Because of its longer roots and high tensile strength, this grass is resistant to the high velocity streams and checks the bank erosion and hence used effectively for bank protection. Vetivers having following properties are desirable for bank protection.

Table 8-1: Properties of Vetiver as erosion control plant

S.N.	Descriptions	Desired Property
1	Average tensile strength	75 MPa
2	Root length	Up to 3 m
3	Life under 14 m of water	Up to 5 months
4	Air temperature range for sustainability	-140C to 550C
5	Soil PH	3 to 10

(3) Plantation

The surface to be planted by vetiver shall be thoroughly cleaned and alignment shall be fixed at the spacing of 80 cm. Pits of size 20 cm * 20 cm * 20 cm shall be made along the alignments at the spacing of 80 cm. Specified quantity of chemical fertilizer along with compost manures shall be used in each pit and plantation operation shall be carried out followed by watering and bamboo fencing for protection.

(4) Measurement and Payment

All items of works related to Napier grass plantation except bamboo fencing shall be measured in hectare of area of plantation works performed. Bamboo fencing works shall be measured in running meter. Payment of respective items of works shall be made at contract unit rates mentioned in BOQ of contract. It shall be the full and final compensation to the contractor as specified in clause 115.

1713 BENCH TERRACING

Bench terracing (Preparation of bench and plantation for protection) is widely used for slope stability and protection. In this process, benches of specified width are cut in the sloped ground at specified interval and plantation at specified interval along the benches are done following the usual process of plantation. Planted area is protected by low cost fencing such as bamboo fencing as bamboos are easily available locally.

All items of completed works related to bench terracing shall be measured in respective units as specified in the contract. Payment of respective items of works shall be made at contract unit rates mentioned in BOQ of contract. It shall be the full and final compensation to the contractor as specified in clause 115.

SECTION 1800: TUNNELING WORKS

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1801 SCOPE OF WORK

This Section covers the materials, methods, workmanship and safety requirements for the construction of tunnels and other related underground structures. The Specification is divided into: (A) General works that apply to all tunnelling methods; (B) Drill & Blast method specific works; and (C) TBM method specific works. Items that are method-specific (for example lining, grouting, TBM consumables, TBM progress rates, blasting procedures) are presented separately under their respective method sections. Common requirements (safety, ventilation, portals, communications, environmental controls, records and measurement rules that apply to both methods) are combined here to avoid duplication.

1802 GENERAL REQUIREMENTS

(1) Standards and References

Tunnel features (dimensions, cross sections, shapes, orientations, support types, lining types and construction sequences) for drill and blast method shall conform to the standards and guidance of JSCE 2006 Mountain Tunnel specifications, NEXCO Section 3 design standards, and JRA technical standards and to recognized international practice. For TBM method ITA guidelines and recognized international practice shall be followed. The Contractor shall identify all standards referenced in method statements and submit any deviations for the Engineer's approval.

(2) Contractor's General Obligations

The Contractor is responsible for all tunnelling works as specified in the Contract and for ensuring safe, timely and quality execution. Approval of materials or methods by the Engineer does not relieve the Contractor of responsibility for performance, safety or compliance.

(3) Safety of Personnel

- The Contractor shall prepare and implement a Tunnel Safety Plan covering: PPE, entry/exit control, daily toolbox talks, emergency evacuation, fire prevention and firefighting, confined-space procedures, rescue arrangements and safety training records.
- PPE shall include head protection, respiratory protection, eye protection, hearing protection and high-visibility clothing of types approved by local authorities.
- The Contractor shall maintain a register of all personnel authorised to enter tunnels and shall operate an entry/exit control system at each portal.

(4) Ventilation and Air Quality

- The Contractor shall design and operate ventilation systems to provide breathable air and to control dust and exhaust gases. Ventilation design shall be supported by calculations showing fan capacities, duct diameters, and expected airflows.
- Minimum fresh air supply at the face shall not be less than 3 m^3/min/person; target respirable dust concentration shall be ≤ 3 mg/m^3 measured at 50 m from the face; minimum air velocity shall be ≥ 0.3 m/s; maximum ambient temperature shall be < 30°C unless otherwise approved.
- Continuous monitoring of oxygen and noxious gases shall be carried out. Entry into tunnels is prohibited if oxygen < 18% or CO_2 > 0.5% (5000 ppm) until safe conditions are confirmed.

(5) Lighting, Electrical and Temporary Installations

- Lighting shall provide at least 70 lux at working faces and a minimum of 10 lux in walkways (20 lux average desirable). Temporary electrical installations shall comply with local regulations; certificates shall be provided if requested. A competent person shall be appointed to oversee electrical safety.

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(6) Communication Systems

The Contractor shall provide wired and wireless communications capable of clear, dependable contact between face, portals and site offices. Underground telephone stations or receptacles shall be provided within 50 m of any work and at 100 m intervals along the driven tunnel.

(7) Portal Works and Access Control

Portal areas, TBM entry/exit platforms (where applicable), and starter tunnel portals shall be secured and stabilized. Fencing, barricades, signage and 24-hour security shall be provided to prevent unauthorized access. Portal drainage, sedimentation ponds and temporary access roads shall be constructed and maintained as required.

(8) Environmental Controls and Water Management

- The Contractor shall provide sedimentation and treatment systems at portals to treat tunnel discharge. Settlement ponds shall be lined and fenced; outflows shall prevent erosion and floating oil discharge. Temporary drains and pipelines shall be sized to handle expected maximum initial flows (minimum 2.5 m^3/min unless otherwise approved).
- Contaminated soils or groundwater shall be handled and disposed of in accordance with the Engineer's directions and environmental regulations.

(9) Surveying, Face Mapping and Records

The Contractor shall maintain accurate survey control and submit daily records including: duration of sequential excavation, personnel on site, work stoppages and reasons, instrument readings, tunnel water inflows, size of excavated sections, length of advance, station numbers, and photographs of faces (minimum 12 MP). Geological mapping and face logs shall be prepared for each advance and submitted daily. Any substantial deviation from anticipated geology shall be reported immediately.

(10) Emergency Preparedness and Training

The Contractor shall prepare emergency response procedures, maintain rescue equipment, and provide training and drills. Emergency contact lists and evacuation procedures shall be distributed to all personnel and posted at portals.

(11) Measurement and Payment Principles Common to Both Methods

Measurement is not performed for the Works described in this Section 1802. The Works required under this section is a subsidiary obligation of the Contractor. Payment for such Works is indirectly included under the pay items listed in the contract or the BOQ.

1803 PART A DRILL & BLAST METHOD

This Part covers all works, materials, methods, workmanship, safety and quality control requirements specific to Drill & Blast tunnelling. Items that are common to all tunnelling methods (safety, ventilation, portals, communications, environmental controls, records and general measurement principles) are specified in Section 1802 GENERAL REQUIREMENTS and apply here unless otherwise stated.

1804 SCOPE OF WORK (DRILL & BLAST)

- Execution of tunnel excavation by drilling and blasting to the neat lines (pay line) and levels shown on the Drawings or as directed by the Engineer.
- All associated activities including probe drilling, drilling for blasting, blasting operations, mucking, haulage and disposal of spoil, temporary and permanent support installation (steel ribs, rock bolts, shotcrete), face mapping, instrumentation, temporary services, and reinstatement of working areas.
- Provision of all labour, plant, explosives, accessories, consumables, temporary works and safety measures necessary to complete the works.

1805 CONSTRUCTION REQUIREMENTS

(1) Method Statement and Programme

- The Contractor shall submit, not less than 28 days before commencing drill & blast excavation, a detailed method statement covering: sequence of operations; Linear Scheduling Method (LSM) time-distance diagram; organization chart with names and responsibilities for each shift; equipment lists with capacities and guaranteed outputs; temporary works (ventilation, lighting, drainage, mucking, access); blasting plan; emergency and evacuation procedures; quality control and monitoring procedures.
- The method statement shall include procedures for probe drilling, face mapping, blast design, misfire treatment, vibration control, and environmental mitigation. No significant alteration to the approved method shall be made without the Engineer's prior written approval.

(2) Probing and Pre-excavation Investigation

- Probe drilling shall be carried out ahead of the face to detect cavities, water inflows, weak zones, faults and other anomalies. Probe hole diameters, lengths and spacing shall be proposed by the Contractor and approved by the Engineer.
- Probe results shall be logged and submitted daily. Where probe drilling indicates adverse conditions, the Contractor shall propose remedial measures (pre-grouting, forepoling, reduced round lengths) for the Engineer's approval.

(3) Blasting Design and Control

- The Contractor shall obtain all statutory licences for explosives, provide secure storage, and nominate qualified shot-firers. Names and qualifications of personnel handling explosives shall be submitted to the Engineer prior to any blasting.
- Blasting plans shall be prepared for each round and shall include: drill pattern, hole diameters and depths, stemming lengths, type and quantity of explosives, detonator types and delay sequencing, charge per hole, and predicted vibration levels. Blasting plans shall be compatible with ground conditions and designed to minimise overbreak and damage to permanent works.
- Where required by the Engineer, the Contractor shall adopt controlled blasting techniques (pre-splitting, smooth blasting, cushion blasting, reduced charge per delay) to limit overbreak and vibration.
- Notices of blasting operations shall be posted and audible warnings given before each shot. The Contractor shall ensure exclusion of personnel from danger zones and maintain a safe perimeter during blasting.
- The Contractor shall maintain a blast log for every shot recording time, location, drill pattern, explosive types and weights, detonators used, delay sequence, and post-blast observations. Blast logs shall be available to the Engineer at the end of each shift.

(4) Misfires and Safety

- Procedures for misfire detection, treatment and reporting shall be included in the method statement. Misfires shall be treated only by qualified personnel following approved procedures. The Engineer shall be notified immediately of any misfire.
- All blasting operations shall comply with applicable national laws and regulations governing explosives and their use. The Contractor shall be responsible for obtaining permits and for safe storage, transport and handling of explosives.

(5) Excavation Sequence and Face Preparation

- Excavation shall proceed in rounds of the length shown on the Drawings or as approved by the Engineer. Deviations from specified round lengths require prior approval.

- After each blast, loose and shattered rock shall be removed by scaling and other means before personnel are permitted to approach the face. The Contractor shall install temporary supports immediately where required for safety.

(6) Temporary and Permanent Support

- Temporary supports (steel ribs, timber lagging, mesh, shotcrete) shall be installed as soon as practicable after excavation to secure the face and working space. Permanent supports (rock bolts, shotcrete with reinforcement, cast-in-situ concrete lining) shall be installed in accordance with the Drawings and Clause 1806/1807.
- The Contractor shall propose support types and installation sequences in the method statement and shall adjust supports based on face mapping and Engineer's instructions.

(7) Shotcrete Application (Temporary and Permanent)

Shotcrete works shall comply with Clause 1806. For Drill & Blast works, shotcrete may be applied as temporary support immediately after excavation and as permanent lining where specified. Application rates, thickness classes and reinforcement (steel fibres, mesh) shall follow the Drawings or Engineer's direction.

(8) Rock Bolts and Anchors

Rock bolt installation shall comply with Clause 1807. Drilling holes up to 38 mm dia and supplying/fixing 25 mm dia rock bolts (or as specified) with bearing plates, nuts and washers shall be executed as per drawings and Engineer's instructions. Holes shall be cleaned prior to fixing.

(9) Mucking, Haulage and Disposal

- Muck haulage shall be planned to avoid damage to supports and services. Haulage equipment dimensions shall be compatible with tunnel profile and installed supports.
- Excavated material shall be transported to designated disposal sites shown on the Drawings or as directed by the Engineer. Portal areas shall not be used for temporary storage except where specifically permitted.
- The Contractor shall maintain records of haulage trips and volumes. Materials suitable for reuse shall be segregated and stockpiled as directed.
- Water Control and Dewatering
- The Contractor shall provide dewatering and drainage systems to control groundwater inflows. Settlement ponds, silt traps and treatment systems shall be provided at portals. Discharge shall comply with environmental requirements.

1806 SAFETY, MONITORING AND ENVIRONMENT (DRILL & BLAST)

(1) Air Quality and Ventilation

Ventilation shall be provided to dilute blast fumes, dust and diesel exhaust. Minimum fresh air supply, dust limits and monitoring procedures are as specified in Section 1802. Continuous gas monitoring shall be carried out and recorded.

(2) Vibration and Noise Monitoring

Where blasting is carried out near structures or sensitive receptors, the Contractor shall implement vibration and noise monitoring. Pre-blast condition surveys of nearby structures are recommended. Vibration limits shall be specified in the method statement and agreed with the Engineer.

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(3) Environmental Protection

Measures to prevent siltation, contamination and erosion from portal works and spoil disposal shall be implemented. Settlement ponds shall be lined and fenced. Any contaminated soils shall be handled and disposed of as directed.

(4) Emergency Procedures

Emergency evacuation and resuming procedures for blasting incidents, misfires, fires and other emergencies shall be included in the Contractor's safety plan. Rescue equipment and trained personnel shall be available.

1807 QUALITY CONTROL, TESTING AND ACCEPTANCE

(1) Face Mapping and Geological Records

The Contractor shall prepare geological maps and face logs for each round. These shall include rock mass classification, discontinuities, water inflows and any anomalies. Records shall be submitted daily.

(2) Inspection and Acceptance of Excavation

Excavation shall be inspected by the Engineer prior to installation of permanent supports. Any loose or over-excavated areas shall be made good as directed. Overbreak is deemed included in the unit rates unless otherwise stated.

(3) Testing of Shotcrete and Anchors

Shotcrete and rock bolt materials shall be tested in accordance with Clause 1806 and 1807. Test certificates and mix designs shall be submitted for approval.

1808 SUBMITTALS (DRILL & BLAST)

The Contractor shall submit the following for the Engineer's review and approval prior to commencing drill & blast works:

1. Detailed method statement and LSM (Time-Distance diagram).
2. Organization Chart; it should show individual names and the line of responsibility amongst the different working shifts.
3. Blasting plans and explosives storage/handling arrangements.
4. Names and qualifications of shot-firers and explosives handlers.
5. Probe drilling plan and reporting format.
6. Support installation procedures (rock bolts, steel ribs, shotcrete).
7. Ventilation and air quality calculations.
8. Muck haulage and disposal plan.
9. Environmental protection and sedimentation pond design.
10. Emergency and evacuation procedures including misfire treatment.
11. Quality control plan and testing schedule.

The Contractor shall not make significant alteration to the method or arrangement without having such alteration previously been notified to the Engineer.

The Contractor shall also submit to the Engineer all deformation monitoring survey data on a daily basis, and other survey data including geological mapping and geological investigation surveys as soon as possible as requested by the Engineer.

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1809 MEASUREMENT AND PAYMENT (DRILL & BLAST)

(1) General Principles

- The quantities of tunnel excavation shall be measured in the unit of measurement specified in the Bill of Quantities along the centerline between the portal crowns for the main tunnel and the evacuation tunnel. Excavation below the portal crown shall be measured in the unit of measurement specified in the Bill of Quantities for payment under Section 300 - Earthworks of the Standard Specifications for Irrigation and River Training Works.
- Measurement of the excavation for cross passages and working Adit shall be performed along the centerline at the height of the spring line. No separate remuneration shall be made for excavation above and below the spring line of the cross passages and the working Adit where it inter. The cost of excavation above and below the spring line shall be included in the unit rates for excavation.
- The Contractor shall submit survey data showing the coordinates of the start points on the portal crowns for agreement with the Engineer. The Contractor shall not commence tunnel excavation unless the Engineer agrees with the survey data.
- The costs contingent to such over break is deemed to have been included in the rates and prices in the Bill of Quantities based on the average thickness of over break shown on the Drawings.
- Note that removal and reinstallation/replacement of pre-supports (fore poles; length being 3.0 m or less, and fore-piles; length exceeding 3 m), steel ribs, wire mesh, rock bolts, shotcrete, and other incidental parts of these supports, as required necessarily in the course of excavation are not subject to separate payment; all of these activities are combined into the direct cost as incidentals necessary to complete a round of excavation irrespective of rock classifications encountered.
- Measurement shall follow the rules set out in Section 1802. Quantities for drill & blast excavation shall be measured along the centreline between portal crowns or as specified in the BOQ. Payment shall be made at the unit rates in the BOQ unless otherwise stated.

(2) Overbreak

- In tunnel excavation using high explosives through rock, the effects of explosive action may well extend more than the tunnel diameter outside the designed finished surface; a good deal of over break is likely unavoidable. Over break will result in increased thickness of shotcrete lining and final concrete lining larger than design thickness.
- Since over break is almost an inevitable result in rock tunneling, the effects of over break in respect of payment shall be deemed taken into the rates and prices entered into the Bill of Quantities; thus, no payment will be made for over break beyond the pay line. Accordingly, the Contractor will be required to employ experienced, skilled and qualified blasting technicians so that over break can be controlled.
- Overbreak beyond the pay line is generally deemed included in the unit rates for excavation. Where the Contract provides for separate measurement of overbreak or remedial works, such provisions shall apply.

(3) Recesses (Niches)

Quantity of recess excavation shall not be measured for payment. Such quantity is deemed included in the measurement of linear meter of excavation in each profile.

(4) Partial Cut off

- Steel ribs installed at the junctions with cross passages and niches shall be partially cut off and modified as indicated on the relevant Drawings.
- The Contractor shall remove the steel ribs, the reinforced shotcrete protection and rock bolts to the dimensions necessary to accommodate the openings in the lining concrete.

(5) Payments

- Payment shall be made on condition that all initial support systems are installed according to the Drawings. Especially in the case of early-closer as an auxiliary construction method, the works, invert

excavation, shotcrete, and backfilling, shall not be measured and paid separately, but shall be deemed included into the rates for unit prices of respective main items. However, the work contents, re-excavation, invert concrete, and backfilling, for final lining shall be deemed included into rates for unit prices of pay-items in the Section Concrete Lining.

- Related temporary facility works and operation (concrete batching plant, power supply, water supply, drainage, lighting etc.) shall not be measured and paid separately, but shall be deemed included into the rates for unit prices of respective main excavation items. In addition, all necessary works for controlling the dust, emission of gas and ventilating air flow inside tunnel shall be deemed included into this Section pay items.
- Payment will be inclusive of difficulties in dealing with groundwater inflow being less than 10 liters per second at the face, and other potential difficulties attributable to the ground conditions that are obviously anticipated from the parameters indicated in the Contract Documents.

(6) Records for Payment

The Contractor shall maintain daily records of rounds, blast logs, muck volumes, support installation and testing. These records shall be submitted with payment claims.

(7) INCIDENTALS AND CONTRACTOR'S RESPONSIBILITIES

- The Contractor's rates shall include provision for all labour, plant, materials, temporary works, supervision, safety measures, permits, licences and incidental works necessary to complete the drill & blast tunnelling works.
- The Contractor shall be responsible for any damage caused by blasting to existing structures where such damage results from non-compliance with approved blasting procedures.

(8) TRANSITION TO OTHER METHODS

Where the Contract or Engineer directs a change in Drill & Blast method for any tunnel section, the Contractor shall prepare a transition plan covering interface works, temporary supports, portal modifications and any additional measures required to safely effect the change. Payment for transition works shall be as per Contract provisions.

1810 STEEL RIB

(1) Scope

This Clause covers the supply, fabrication, erection, corrosion protection, inspection, and acceptance of steel ribs used as tunnel supports. Steel ribs may be temporary or permanent depending on ground conditions and design requirements.

(2) Materials

- **Steel grade**: JIS G3101 SS400 or JIS G3106 SM490 (yield strength ≥ 235 MPa for SS400, ≥ 325 MPa for SM490).
- **Sections**: Rolled I-beams, channels, or fabricated curved ribs as shown on Drawings.
- **Bolts/nuts/washers**: High-strength bolts conforming to JIS B1180.
- **Lagging**: Timber (treated per JIS A 9002) or steel plates.
- **Corrosion protection**: Shop primer (JIS K 5621) and field painting; galvanizing where specified.

(3) Fabrication

- Fabrication shall follow JIS Z 3801 welding standards.
- Welders shall be certified per JIS Z 3805.
- Dimensional tolerances: ±5 mm for rib curvature, ±3 mm for bolt hole spacing.

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(4) Erection

- Spacing: 0.75–1.5 m depending on ground class (JSCE Mountain Tunnel).
- Bearing plates shall be installed at rib feet.
- Lagging fitted tightly against rock to prevent local falls.
- Temporary bracing provided during erection.

(5) Inspection and Testing

- Visual inspection of welds and bolt torque checks.
- NDT (ultrasonic or radiographic) for 10% of site welds.
- Corrosion protection thickness measured at 3 points per rib.

(6) Measurement and Payment

- Measured per set or tonne as per BOQ.
- Rates include supply, fabrication, transport, erection, lagging, corrosion protection, and removal (if temporary).

1811 SHOTCRETE

(1) Scope

It covers wet-mix and dry-mix shotcrete used for temporary and permanent tunnel lining.

(2) Mix Design (JSCE/NEXCO/JRA)

- Cement: Ordinary Portland Cement (JIS R 5210).
- Cement content: ≥ 400 kg/m³.
- Water/cement ratio: ≤ 0.45.
- Aggregate: Max size 10 mm, conforming to JIS A 5005.
- Steel fibres: 40–60 kg/m³, length 30–35 mm, tensile strength ≥ 1,100 MPa.
- Admixtures: Accelerators (alkali-free preferred), plasticizers as approved.

(3) Thickness Classes

- Class A: ≤100 mm (temporary).
- Class B: 100–150 mm (intermediate).
- Class C: 150–200 mm (permanent). Thickness determined by ground class per JSCE.

(4) Application

- Surface cleaned and pre-wetted.
- Mesh or lattice girders fixed before spraying.
- Layers applied ≤ 75 mm per pass to avoid rebound.
- Rebound removed immediately.

(5) Curing

- Maintain moisture for ≥ 7 days.
- Curing compounds per JIS A 6910 may be used.

(6) Testing Frequency (JSCE)

- Compressive strength: 3 cores per 50 m tunnel length.
- Thickness checks: 1 per 10 m².
- Bond pull-off tests: 1 per 100 m².
- Fibre dosage verification: 1 sample per 50 m³ shotcrete.

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(7) Acceptance

- 28-day compressive strength ≥ 25 MPa (temporary), ≥ 30 MPa (permanent).
- Thickness within ±10 mm of specified.
- Bond strength ≥ 1.0 MPa.

(8) Measurement and Payment

- Measured by area (m²) or volume (m³) per thickness class.
- Rates include surface preparation, reinforcement, application, curing, and testing.

1812 ROCK BOLT

(1) Scope

It covers drilling, supply, installation, grouting, tensioning, and testing of rock bolts.

(2) Materials

- **Bolt type**: Fully grouted rebar bolts, diameter 25–32 mm (JIS G3112 SD345 steel).
- **Length**: 2–4 m depending on ground class.
- **Bearing plates**: 150 × 150 × 10 mm minimum, steel grade SS400.
- **Grout**: Cement grout w/c ≤ 0.5, OPC per JIS R 5210.
- **Resin cartridges**: Allowed for short bolts in hard rock.

(3) Installation

- Drill holes 38–45 mm diameter, cleaned with air/water.
- Insert bolt, grout from bottom up using tremie tube.
- Torque nuts to 120–150 Nm.
- Corrosion protection: galvanized or epoxy-coated bolts for permanent works.

(4) Testing Frequency (JSCE/NEXCO/JRA)

- Pull-out tests: 1 per 50 bolts.
- Torque checks: every bolt.
- Grout cube strength: 1 set per 20 m³ grout.

(5) Acceptance Criteria

- Pull-out capacity ≥ 100 kN for 25 mm bolts, ≥ 150 kN for 32 mm bolts.
- Grout compressive strength ≥ 25 MPa at 28 days.
- No voids or incomplete grouting.

(6) Measurement and Payment

- Measured per bolt installed.
- Rates include drilling, cleaning, bolt supply, grout, bearing plates, nuts, tensioning, testing, and records.

1813 TUNNEL PORTALS (Supply, Fabrication, and Erection of Steel Portals with Lagging and Concrete)

(1) Scope of Work

The work under this section consists of **supplying, fabricating, transporting, erecting, and installing** steel portal frames, including steel lagging, tie rods, bracing, and the placement of concrete lining or backfill concrete to the specified line and grade. All operations shall be carried out in strict accordance with these

specifications, the approved construction drawings, the International Tunnelling and Underground Space Association (ITA) guidelines, and the directions of the Engineer.

(2) Applicable Reference Standards

All materials and workmanship shall comply with the latest revisions of the following standards. In case of conflicting requirements, the guidelines of the **ITA** or the explicit instructions of the Engineer shall take precedence.

(i) Structural Steel and Fabrication

- **JIS G 3101:** Rolled Steels for General Structure (SS400, etc.).
- **JIS G 3106:** Rolled Steels for Welded Structure (SM400, SM490, etc.).
- **JIS G 3192:** Dimensions, Mass, and Permissible Variations of Hot Rolled Steel Sections.
- **IS 2062:** Hot Rolled Medium and High Tensile Structural Steel.

(ii) Tunneling Guidelines & Support Systems

- **ITA Guidelines:** Guidelines for the Design of Tunnels / Guidelines for the Selection of Tunnel Support Systems.
- **JASCE Guidelines:** Standard Specifications for Tunneling (Tunnel Engineering Committee of Japan Society of Civil Engineers).

(iii) Concrete Works

- **IS 456:** Plain and Reinforced Concrete — Code of Practice.
- **IS 10262:** Guidelines for Concrete Mix Design.
- **JIS A 5308:** Ready-Mixed Concrete.
- **Standard Specifications for Concrete Structures (JSCE):** Materials and Construction.

(iv) Welding and Fasteners

- **JIS Z 3801 / IS 7307:** Standard Qualification Test for Welding Procedure.
- **JIS B 1186 / IS 1367:** Sets of High Strength Hexagon Bolts, Hexagon Nuts, and Plain Washers for Friction Grip Joints.

(3) Material Requirements

(i) Structural Steel

- All structural steel sections (H-beams, I-beams, channels, angles, and plates) utilized for portal frames shall be brand new, free from laminations, cracks, excessive rust, and surface defects.
- Materials must meet the chemical and mechanical properties specified in **JIS G 3101/3106** or **IS 2062**.
- Mill Test Certificates (MTC) matching the heat numbers of delivered batches must be submitted prior to fabrication.

(ii) Steel Lagging and Accessories

- Steel lagging (liner plates, corrugated sheets, or channels) shall conform to **JIS G 3101** or **IS 2062** standards and match the design thickness shown on the approved drawings.
- Tie rods, spacing struts, rock bolts connections, and fasteners shall conform to standard structural steel grades and be compatible with the frame configuration.

(iii) Concrete

- Concrete for the portal arch lining, base footing, or rock-backfill encasement shall be of the specified design mix class (e.g., **IS Code classes M25, M30, M35** or equivalent JSCE designations).
- Cement, aggregates, water, and chemical/mineral admixtures shall strictly comply with the requirements of **IS 456** and **IS 9103** / **JIS A 5308**.

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(4) Fabrication

(i) Workmanship

- Fabrication shall be carried out in an approved, covered workshop or a dedicated, controlled on-site fabrication yard.
- All steel components shall be cut, bent, rolled, and shaped accurately to the radii and profiles specified in the approved shop drawings.
- Cold bending of heavy sections shall be avoided unless done using heavy-duty bending rollers that prevent deformation or buckling of the flanges and webs.

(ii) Welding

- Welding procedures shall be qualified in accordance with **IS 7307 / JIS Z 3801** protocols.
- Only certified, experienced welders shall perform structural welding.
- Low-hydrogen electrodes compatible with the base metal grade shall be used, stored, and baked according to manufacturer guidelines.
- All critical structural welds (splices and heavy connection plates) shall undergo **Non-Destructive Testing (NDT)**—including Visual Inspection, Magnetic Particle Testing (MPT), and Ultrasonic Testing (UT)—as stipulated by the Engineer.

(5) Transportation, Storage, and Handling

- Fabricated steel frame components shall be handled using nylon slings and multi-point lifting beams to prevent permanent twisting, distortion, or mechanical damage.
- Steel components shall be stored off the ground on concrete blocks or timber sleepers in a well-drained yard to prevent rust, scale formation, or contact with dirt.

(6) Erection and Installation

(i) Alignment and Geometry

- Prior to placing the steel portal, the excavation limits, centerline, and invert levels shall be established by precise geodetic survey in accordance with **ITA guidelines**.
- The steel portals shall be erected rigidly to the exact structural line, grade, and inclination using specialized portal lifters, cranes, and temporary rigid props/struts.
- The tolerance for positioning the frame centerlines shall not exceed **±10 mm**, and deviation from the design verticality/inclination plane shall not exceed **1 in 200**, unless tighter tolerances are designated by the Engineer.

(ii) Connection and Fastening

- Splice connections between segments of the portal frames shall be tightly brought together and bolted using high-strength friction grip (HSFG) bolts to **JIS B 1186 / IS 1367** specifications or fully welded as per drawing requirements.
- Torque wrenches used for tightening shall be calibrated daily.

(iii) Installation of Steel Lagging

- Steel lagging shall be fixed sequentially to the exterior face of the steel portal arches as excavation/advancement proceeds.
- Lagging sheets must be firmly secured via tie rods, hook bolts, or localized welding to create a continuous, rigid canopy capable of safely holding the ground pressure and confining the wet concrete backfill.

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(7) Concreting

(i) Preparation

- Before concrete placement, all loose rock, muck, water, grease, and excessive rust scales must be cleared from the steel frames, lagging, and the excavated rock face.
- If structural reinforcement bars are used alongside the steel portal frames, they shall be tied rigidly according to **IS 456 / JSCE guidelines**.

(ii) Placement and Compaction

- Concrete shall be delivered and placed via concrete pumps or concrete placers.
- Concrete must be placed symmetrically on both sides of the portal arch in uniform layers to prevent asymmetric lateral loading, displacement, or structural deformation of the steel frame.
- Internal immersion vibrators (complying with **IS 2505**) and external form vibrators (where required) shall be used systematically to eliminate air pockets, honeycombing, and voids behind the steel lagging.
- Curing shall be initiated immediately after the removal of formwork. Concrete shall be kept continuously damp/wet for at least **14 days** for ordinary Portland cement, or as per the requirements of **IS 456 / JSCE** for blended cements.

(8) Quality Control and Inspection

- **Material Testing:** Sampling and testing of structural steel and concrete blocks/cylinders shall be executed per **JIS/IS** frequencies.
- **Dimensional Surveys:** The Contractor shall submit a structural geometry survey report for each portal frame before concrete pouring is authorized.
- **Concrete Strength:** Cube/cylinder compression testing shall be carried out at 7 days and 28 days as specified in **IS 456 / JIS A 5308**.

(9) Measurement and Payment

- **Measurement Metrics:** Structural steel fabrication/erection will be quantified by weight in **Metric Tons (MT)**. Steel lagging will be measured in **Square Meters (m^2)** or weight basis. Concrete will be measured in **Cubic Meters (m^3)** based on the theoretical line and grade dimensions shown on the drawings.
- **Rate Coverage:** The item rate shall encompass the total cost of raw material supply, waste, fabrication workshop machinery, welding consumables, NDT inspections, site transportation, erection rigging, setting to line and grade, installing lagging, supplying and pouring concrete, curing, and all other incidental works necessary to deliver a completed portal structure to the entire satisfaction of the Engineer.

1814 PART B TBM METHOD

This Part covers all works, materials, methods, workmanship, safety, monitoring and quality control requirements specific to **Tunnel Boring Machine (TBM)** tunnelling. Items common to all tunnelling methods (safety, ventilation, portals, communications, environmental controls, records and general measurement principles) are specified in **Section 1802 GENERAL REQUIREMENTS** and apply here unless otherwise stated. Grouting and lining works that are TBM-specific are included in this Part; where grouting or lining differs for Drill & Blast, those items remain in Part A.

1815 SCOPE OF WORK (TBM)

- Supply, transport, assembly, commissioning, operation, maintenance and retrieval of the TBM and its backup train.

- Excavation, de-mucking, spoil handling, segment erection and sealing, annular space treatment (pea-gravel backfill, grout, mortar), probing ahead of face, umbrella pipe roofing/forepoling where required, pre- and post-grouting associated with TBM advance.
- Provision of TBM consumables, spare parts, cutter replacement, TBM plant (conveyors, segment erectors, backup systems), temporary services and all labour, supervision and temporary works necessary to complete TBM tunnelling.
- Monitoring, instrumentation, face mapping, and reporting specific to TBM operations.

1816 TBM SELECTION, SUBMITTALS AND APPROVALS

(1) TBM Selection and Design Submission

- The Contractor shall propose the TBM type, cutterhead configuration, shield diameter, thrust system, mucking system (belt, screw, slurry), backup layout and segment erection system. Submissions shall include manufacturer's data, design drawings, cutterhead drawings, cutter types and sizes, hydraulic and electrical power requirements, and expected performance curves.
- The Contractor shall submit a TBM Operation and Maintenance (O&M) plan, spare parts list, cutter consumption forecast, and a TBM risk register for Engineer's approval.

(2) TBM Assembly, Commissioning and Trial Runs

Detailed assembly, commissioning and trial run procedures shall be submitted. TBM assembly shall be supervised by qualified personnel and manufacturer's representatives where required. Trial runs shall demonstrate alignment control, mucking, segment erection and backup systems functioning before full advance.

(3) Method Statements and Programmes

The Contractor shall submit TBM method statements not less than 28 days before commencing TBM excavation. Method statements shall include: LSM (Time-Distance diagram) with working and maintenance shifts, TBM advance and maintenance schedules, cutter replacement strategy, spare parts inventory, emergency stop and retrieval procedures, and contingency plans for extraordinary ground conditions.

1817 TBM OPERATIONS AND ORGANISATION

(1) Organization and Shifts

The Contractor shall provide organization charts showing TBM crew, backup crew, maintenance teams and shift rosters. TBM operations shall be planned in working shifts and maintenance shifts; the number of shifts and staffing levels shall be included in the LSM.

(2) Working Shift (Excavation Shift)

Working shifts shall cover continuous TBM advance, de-mucking, segment erection, face probing and immediate grouting/backfilling as required. The Contractor shall ensure adequate personnel for safe and continuous operation, including face observers and quality control staff.

(3) Maintenance Shift

Maintenance shifts shall be scheduled for cutter replacement, mechanical inspections, lubrication, hydraulic checks and other preventive maintenance. The Contractor shall maintain a stock of spare cutters, cutter holders, seals and critical spares to avoid prolonged TBM downtime.

(4) TBM Control and Guidance

TBM guidance and alignment systems shall be provided and maintained. Procedures for alignment checks, ring geometry verification and corrective actions shall be submitted. Tolerances for alignment and ring geometry shall be as specified in the Contract or as approved by the Engineer.

1818 TBM EXCAVATION PROCEDURES

(1) Face Observation and Mapping

The Contractor shall implement a face observation regime including manhole inspections, face photography, geological logging and rock mass classification at intervals specified in the method statement. Face mapping records shall be submitted daily.

(2) Probing Ahead of Face

Probing shall be carried out ahead of the TBM face for investigation, drainage, forepoling, umbrella pipe roofing and pre-excavation grouting. Typical probe hole diameter up to **75 mm** and lengths up to **30 m** may be used where required. Probe spacing, pattern and frequency shall be defined in the method statement and adjusted based on ground conditions. Costs of routine probing are included in TBM item rates unless otherwise stated.

(3) Advance Control and Ring Erection

TBM advance shall be controlled to ensure ring quality and to limit ground disturbance. Segment erection sequence, gasket installation, ring bolting and grout injection procedures shall be as per segment manufacturer's recommendations and the approved method statement. The Contractor shall ensure immediate verification of ring geometry and sealing after erection.

(4) De-mucking and Spoil Handling

Muck removal shall be by conveyor, rail or slurry system as proposed. The Contractor shall ensure continuous spoil handling capacity to prevent TBM stoppage. Spoil transfer points, rotary dumping systems and disposal arrangements shall be included in the method statement.

1819 TBM SUPPORT AND GROUND TREATMENT

(1) Annular Space Treatment

- **Pea Gravel Backfilling**: Placement of pea gravel in the annular space between the excavated rock and the external face of the segment lining shall be carried out to the lines and grades shown. Pea gravel gradation, compaction and placement procedures shall be submitted. Pea gravel may also be used for similar packing works (e.g., behind retaining walls).
- **Pea Gravel Grouting (without packers)**: Grout mix water:cement ratio **0.5:1**. Injection procedures, pressures and volumes shall be specified.
- **Pea Gravel Grouting (with packers)**: Where controlled injection is required, packers shall be used. Grout mix and injection control shall follow approved procedures.
- **Backfilling of Annular Space with Cement Sand Mortar**: Where specified (e.g., invert annular space), backfill with **M25** cement sand mortar shall be carried out in accordance with the method statement and segment manufacturer's guidance.

(2) Pre-excavation and Consolidation Grouting

Pre-excavation grouting for portal approaches, fault zones or weak ground shall be carried out using approved grout mixes (water:cement ratio **0.5:1** unless otherwise specified). Grouting patterns, pressures, and acceptance criteria shall be submitted. Grouting records (injection volumes, pressures, grout take) shall be maintained.

(3) Umbrella Pipe Roofing and Forepoling

Where required for weak ground or fault zones, umbrella pipe roofing and forepoles shall be installed ahead of the TBM face. Design, spacing, insertion method and grouting of umbrella pipes shall be included in the method statement. Installation shall be coordinated with TBM advance to maintain face stability.

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(4) Drainage and Relief Measures

Drainage pipes installed in the invert or behind lining shall be provided where required. Relief holes, drainage galleries or other measures to control groundwater shall be implemented as per the approved design.

1820 TBM CONSUMABLES, SPARES AND PLANTS

(1) Cutter Tools and Consumption

The Contractor shall supply cutters, cutter holders and associated tooling. A **Cutter Consumption Table** (Annex Table 1) showing cutter type, expected life (m or hours), replacement frequency and unit rates shall be submitted. Cutter replacement procedures and safety measures shall be included in the method statement.

(2) Grout, Cement and Pea Gravel

The Contractor shall supply grout materials, cement, sand and pea gravel of specified gradation and quality. Mix designs, batching and placement procedures shall be submitted for approval.

(3) TBM Plants and Backup Systems

The Contractor shall provide backup train equipment including segment erectors, conveyors, muck pumps (if slurry), ventilation fans, power generation, hydraulic and electrical control units, segment storage and handling cranes. Plant capacities and redundancy arrangements shall be included in the submission.

(4) Consumables Inventory and Spares

The Contractor shall maintain an on-site inventory of critical spares (cutters, seals, bearings, hydraulic hoses, gaskets) sufficient to maintain TBM operation without undue delay. A minimum stock list and reorder thresholds shall be submitted.

1821 TBM MAINTENANCE, REPAIR AND RETRIEVAL

(1) Scheduled Maintenance

The Contractor shall prepare a scheduled maintenance plan including daily, weekly and major maintenance activities. Maintenance windows shall be included in the LSM and coordinated to minimise impact on advance.

(2) Cutter Replacement and Major Overhauls

Cutter replacement procedures, safety arrangements and record keeping shall be provided. Major overhauls shall be carried out in designated maintenance areas and recorded.

(3) TBM Retrieval and Demobilisation

Procedures for TBM retrieval at the exit platform, disassembly, transport and demobilisation shall be submitted. TBM retrieval works shall be executed without causing environmental harm or undue disruption to other works. Costs for retrieval shall be included in the TBM lump sum or as specified in the BOQ.

1822 TBM SAFETY, MONITORING AND INSTRUMENTATION

(1) Face and Ground Monitoring

Continuous monitoring of face conditions, ring erection quality, segment alignment, and groundwater inflows shall be carried out. Instrumentation (inclinometers, piezometers, extensometers) shall be installed where required and readings submitted daily.

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(2) Air Quality and Ventilation

Ventilation for TBM operations shall meet the requirements of Section 1802. TBM backup areas and maintenance zones shall have adequate ventilation and exhaust control.

(3) Emergency Procedures Specific to TBM

Emergency stop, TBM evacuation, rescue and retrieval procedures shall be included in the TBM method statement. Fire suppression systems, gas monitoring and escape routes in the TBM and backup train shall be provided.

1823 QUALITY CONTROL, TESTING AND ACCEPTANCE (TBM)

(1) Ring and Segment Acceptance

Each ring shall be inspected for geometry, gasket seating and grout/seal acceptance. Acceptance criteria and remedial actions for misaligned or leaking rings shall be defined.

(2) Grout and Backfill Testing

Grout mixes and backfill materials shall be tested for strength, flow and composition. Test results and batch records shall be submitted.

(3) Instrumentation and Reporting

Instrumentation data (inclinometer, piezometer, settlement markers) and TBM performance logs (advance rates, cutter wear, downtime) shall be submitted daily and compiled monthly for the Engineer's review.

1824 MEASUREMENT AND PAYMENT (TBM)

(1) General Principles

TBM excavation shall be measured in running metres of completed tunnel excavated to the neat lines and levels as approved. Unit rates shall include TBM operation, de-mucking, segment erection, annular backfill (pea gravel or mortar where specified), routine probing, routine grouting associated with ring erection, consumables and temporary works unless otherwise stated in the BOQ.

(2) Separate Pay Items

Typical TBM pay items may include: running metre excavation by TBM; TBM mobilization/demobilization (lump sum); probing ahead of face (per m or per hole); pre-excavation grouting (per m^3); segmental lining (per m^3); reinforcement in lining (per metric ton); pea gravel backfill (per m^3); annular mortar backfill (per m^3); drainage pipe installation (per m); TBM plant hire (lump sum or per month). Payment items shall follow the BOQ.

(3) Extraordinary Conditions and Variations

For extraordinary ground conditions (squeezing, geothermal/slabbing/rock bursting, fault zones) additional works such as umbrella roofing, forepoling, extensive pre-grouting, special segment materials or reduced advance rates may be required. Where such works are not included in the unit rates, payment shall be as per Contract variation procedures or as separately itemized in the BOQ.

(4) Records for Payment

The Contractor shall maintain daily TBM logs showing metres advanced, ring counts, cutter changes, downtime, grout volumes, probe holes and grouting records. These records shall accompany payment claims.

1825 ANNEXES (TBM)

- **Table 1 (Annex)**: Cutter Consumption in TBM Tunnelling — cutter type; nominal life (m or hours); replacement frequency; unit cost; expected consumption per 100 m advance.
- **Table 2 (Annex)**: Cost of TBM — capital cost allocation, operation cost per m, maintenance cost per m, consumables cost per m, spare parts contingency.
- **Annex**: Standard forms for TBM daily log, probe log, grout injection log, ring acceptance checklist and cutter replacement record.

1826 SUBMITTALS (TBM)

The Contractor shall submit for approval prior to TBM works commencing:

1. TBM technical data, manufacturer's drawings and performance guarantees.
2. TBM Operation & Maintenance plan and spare parts list.
3. TBM method statement, LSM and shift schedules.
4. Cutter consumption forecast and Table 1 (Annex).
5. TBM plant layout, backup train drawings and power/ventilation calculations.
6. Probing, umbrella roofing and pre-grouting procedures.
7. Grout mix designs, pea gravel gradation and backfill procedures.
8. Emergency, retrieval and rescue procedures specific to TBM.
9. Quality control plan, ring acceptance criteria and instrumentation plan.

1827 CONTRACTOR'S RESPONSIBILITIES (TBM)

- The Contractor's TBM rates shall include all labour, plant, materials, consumables, spare parts, temporary works, supervision, safety measures, permits and incidental works necessary to complete TBM tunnelling unless otherwise stated in the BOQ.
- The Contractor shall be responsible for TBM performance, safe operation, environmental compliance and for remedying defects arising from TBM operations.

1828 SEGMENT LINING (TBM METHOD)

(1) Scope

This Specification covers the design parameters, manufacturing controls, material properties, fabrication of reinforcement cages, handling, storage, installation, and quality assurance criteria for precast reinforced concrete segments used as permanent lining in bored tunnels excavated by Tunnel Boring Machines (TBM).

The Contractor shall provide all labor, plant, materials, molds, tools, and testing facilities necessary to produce, transport, and erect the segments in compliance with the performance requirements defined herein.

(2) Applicable standards & guidelines

All materials, testing, and workmanship shall comply with the latest editions of the following standards:

- ITA WG2 (2019): Guidelines for the Design of Segmental Tunnel Linings (Report No. 22)
- EN 1992-1-1 (Eurocode 2): Design of Concrete Structures – General Rules
- EN 206 / EN 197-1: Concrete – Specification, Performance, Production, and Conformity / Cement
- ISO 6935-2 / BS 4449: Steel for the Reinforcement of Concrete – Ribbed Bars
- EN 10080: Steel for Reinforcement of Concrete – Weldable Reinforcing Steel
- STUVA / DAUB: Guidelines for the Selection and Application of Linings and Gaskets in Shield Tunnels

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(3) Design & performance requirements

(i) Design Load Cases

The segment design shall structurally account for all temporary and permanent loading conditions, including:

- **Production & Logistics:** Stripping from molds, turning, stacking, curing, site transport, and shipping.
- **TBM Execution Phase:** Concentrated thrust forces from TBM hydraulic rams (including eccentricities and shoe misalignments), ring-building assembly, and tail-skin grouting pressures.
- **Permanent Phase:** Asymmetric ground loads, long-term hydrostatic pressure, seismic loads, and structural interactions at cross-passages.

(ii) Durability & Service Life

- Service Life: The structural system shall be designed for a minimum maintenance-free asset service life of 100 years (or as specified in the project data sheets).
- **Concrete Cover:** The minimum nominal concrete cover to the outermost steel reinforcement bar shall be **35 mm** (or up to **40 mm** for aggressive exposure classifications), strictly governed by the relevant environmental exposure classes (e.g., XC, XD, XS, XA according to EN 206).

(4) MATERIAL SPECIFICATIONS

(i) Concrete Mix Design

The concrete matrix shall be an optimized, low-permeability mix engineered for durability and early-age handling strength.

- **Compressive Strength:** Minimum characteristic strength class **C50/60** (minimum \fck, cyl = 50 MPa / f ck, cube = 60 MPa at 28 days).
- **Early Strength:** Minimum structural strength required at stripping shall be explicitly verified to prevent micro-cracking during demolding.
- **Cementitious Content:** Maximum water-to-binder (w/b) ratio shall be **0.38**. Type and blending of cement (e.g., CEM I, CEM II/A-S, or CEM III/A) shall be selected based on chemical exposure and sulfate resistance requirements.
- **Aggregates:** Clean, hard, durable, non-reactive (alkali-silica reaction free), continuously graded with a maximum nominal size D max of **20 mm**.
- Admixtures: Plasticizers, retarders, air entraining agents as approved.
- **Chemical Limits:** Total water-soluble chloride ion content shall not exceed **0.10%** by mass of cementitious material. Maximum water absorption under vacuum shall be **≤ 5.0%**.

(ii) Steel Reinforcement Cages

- **Material Properties:** Reinforcement steel shall consist of high-ductility ribbed bars with a minimum characteristic yield strength f yk of **500 MPa**, complying with ISO 6935-2 or BS 4449 (Grade B500B or B500C).
- **Cage Fabrication:** 3D reinforcement cages shall be fabricated in rigid, automated precision steel jigs to secure structural geometry.
- **Welding & Fixation:** Tack welding for cage assembly is permitted only on weldable steel grades conforming to EN 10080. It must be performed by certified welders or automated robotic welding plants to ensure no localized reduction in the bar cross-section or yield capacity.
- **Spacers:** Heavy-duty, low-permeability concrete or approved plastic spacers shall be securely attached to the cage to maintain the specified clear cover during high-frequency concrete compaction. Spacers shall not induce localized leakage paths.

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(5) MANUFACTURING & TOLERANCES

(i) Molds & Casting

- Segments shall be cast horizontally in high-precision, CNC-machined steel molds equipped with integrated high-frequency vibrators or cast using Self-Consolidating Concrete (SCC).
- The molds shall be structurally rigid enough to resist distortion under dynamic compaction energy and thermal curing cycles.

(ii) Geometric Manufacturing Tolerances

To ensure structural ring buildability and minimize structural stepping or lip formation under high-speed TBM assembly, dimensional variations shall not exceed the values below:

Measurement Parameter	Permissible Tolerance
Segment Width (Along Tunnel Axis)	± 0.5 mm
Arc Length (Outer / Inner Circumference)	± 0.5 mm
Segment Thickness	± 1.0 mm
Flange / Joint Plane Flatness	± 0.3 mm
Bolt Pocket Positions	± 1.0 mm
Gasket Groove Dimensions (Width/Depth)	± 0.5 mm

(6) JOINTS & SEALING SYSTEMS

(i) Gasket Grooves & Profiles

- Each segment shall feature a continuous, cast-in or post-glued gasket groove on all longitudinal and circumferential joints to house an elastomeric sealing profile.
- Gaskets shall be compression-molded EPDM or composite EPDM/hydrophilic profiles designed to provide a watertight seal against the maximum calculated design hydrostatic head multiplied by a **safety factor of ≥ 2.0**.
- The gasket sealing performance must be verified via testing under conditions simulating maximum expected joint opening (gap) and parallel offset (step/rotation).

(ii) Joint Packers / Compression Pads

- Hardwood, bituminous, or synthetic compression pads (packers) shall be applied to the longitudinal joints to distribute compressive forces uniformly across the ring joints and prevent localized concrete spalling during TBM thrust cycles.

(7) Ring Erection Procedures

- Segments erected in sequence per manufacturer's instructions.
- Bolts tightened to torque 200–250 Nm.
- Gasket seating checked visually and by feeler gauge.
- Alignment verified with templates and laser guidance.

(8) QUALITY ASSURANCE & TESTING

The Contractor shall implement a comprehensive Quality Control plan. The minimum testing frequencies for production compliance include:

- **Compressive Strength Testing:** Cube or cylinder sampling per every 50 m³ of concrete poured, or at least once per casting shift. Samples shall be tested for both early-age demolding strength and 28-day characteristic compliance.
- **Dimensional Inspections:** Full dimensional audit of **1 in every 100 segments** produced, using calibrated 3D laser scanners or high-precision mechanical templates.
- **Water Tightness Validation:** Concrete core permeability testing (e.g., DIN 1048 water penetration depth ≤ 20 mm) performed monthly or upon change of mix design.
- **Visual Anomalies:** 100% of segments shall be inspected upon demolding and prior to dispatch. Structural cracks, blowholes exceeding 5mm in diameter, or edge spalling within the gasket seat area shall be grounds for immediate rejection. Remedial repairs for minor cosmetic defects shall only be conducted using approved structural epoxy or micro-mortar patch compounds.

(9) Acceptance Criteria

- Concrete strength ≥ 50 MPa at 28 days.
- Ring geometry within tolerances.
- Gasket compression and leakage test passed.
- Bolt torque verified.

(10) Measurement and Payment

- Measured per ring erected.
- Rates include supply, transport, erection, bolting, gasket installation, and acceptance testing.

1829 ANNULAR BACKFILL AND GROUTING (TBM METHOD)

(1) Scope

This Specification covers the performance criteria, material properties, testing regimes, and placing requirements for the primary and secondary backfill materials injected into the annular gap between the precast concrete segments and the excavated ground profile, including pea gravel backfill, grout injection, and mortar backfill.

(2) APPLICABLE STANDARDS & GUIDELINES

- ITAtech (2014): Guidelines on Best Practices for Segment Backfilling
- EN 196 / EN 445: Methods of Testing Cement / Grout for Prestressing Tendons – Test Procedures
- ASTM C940: Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts

(3) Materials

(i) Pea gravel:

- Grading & Sizing: Clean, naturally rounded river pebble or high-quality crushed rock uniformly graded between 5 mm and 10 mm.
- Geometric Compatibility: The maximum particle diameter (10 mm) shall not exceed one-third (1/3) of the total width of the TBM tail shield clearance (annular gap) and the internal diameters of the pneumatic injection system pipelines to completely eliminate line plugging risks.
- Fines Content: Highly washed, containing less than 1.0% passing the 0.063 mm sieve to preserve open, interconnected pore structures essential for subsequent secondary structural grout infusion.

(ii) Structural annular backfill grout:

- Compressive Strength: The grout mix shall achieve a minimum characteristic compressive strength of ≥ 25 MPa at 28 days. Critical early-age strength at 1 hour shall be explicitly verified to withstand initial TBM structural dead loads without ring displacement.

- Water-to-Binder Management: The maximum water-to-cement (w/c) ratio shall be strictly balanced (target base value 0.50) to minimize segregation. The mix design shall optimize cementitious content and additives to ensure high fluid consistency without compromising structural density.
- Admixture Modifiers: High-range water reducers (plasticizers) and hydration control retarders shall be systematically incorporated to ensure workability and prevent setting within the internal TBM pipework for a minimum of 24 hours, while still displaying rapid reaction once injected.
- Volume Stability & Bleeding: Total bleeding of the fresh mixture under standard atmospheric testing shall be ≤ 1.0% of the volume to eliminate void formations at the tunnel crown.

(iii) Invert backfill mortar:

- Material Properties: Invert clearing zones or structural roadway bedding layers inside the bottom segments shall be cast using a high-workability cement-sand bedding mortar.
- Strength Class: The mortar shall exhibit a minimum characteristic compressive strength of 25 MPa at 28 days (equivalent to an M25 standard application designation). It must be dense, low-shrinkage, and capable of securely anchoring standard internal utilities or heavy multi-service vehicle (MSV) haul tracks.Admixtures: Plasticizers or retarders as approved.

(4) Procedures

- **Pea gravel backfill**: Must be blown continuously through the segment crown or sidewall ports immediately as the TBM tail skin clears the ring. Subsequent structural grouting shall be executed to fully seal the remaining gravel voids.
- **Grout injection (without packers)**: Inject through ports at ≤ 10 bar until grout take reduces.
- **Grout injection (with packers)**: Used for controlled zones; packers inflated, grout injected at specified pressure.
- **Mortar backfill**: Placed in invert annular space using tremie or pump.

(5) Material Testing Frequencies

The Contractor shall implement a comprehensive Quality Assurance and Control program to verify the consistency and performance of all backfill materials. The minimum testing frequencies shall comply with the following schedule:

(i) Annular Backfill Grout Cubes/Cylinders:

- One (1) complete set of specimens shall be sampled for every **50 m³** of grout mixed, or a minimum of one set per TBM working shift, whichever is more frequent.
- Each set shall consist of a sufficient number of specimens to test for both early-age handling strength (if required by the design) and the standard **28-day characteristic compressive strength**.

(ii) Invert Backfill Mortar Cubes/Cylinders:

- One (1) complete set of specimens shall be sampled for every **20 m³** of structural mortar placed within the tunnel invert, or a minimum of one set per casting shift. Specimens shall be tested for compliance at 28 days.

(iii) Pea Gravel Gradation (5–10 mm Sizing):

- One (1) sieve analysis and cleanliness verification test shall be conducted for every **100 m³** of pea gravel delivered to the site, or per batch delivery.
- Testing must explicitly verify that the fines content passing the 0.063 mm sieve remains **≤ 1.0%** to prevent pipeline blockages.

(6) Process Monitoring & Digital Logs

- Real-Time Injection Records:
    - o Automated data-logging systems onboard the TBM shall continuously record the backfilling parameters for **every injection port on every individual segment ring**.

- The digital log must capture and archive *Injection volume (liters per port), actual injection pressure profile (bars), TBM advance rate, and total grout/gravel volume injected per ring*.

(7) ACCEPTANCE CRITERIA

A backfill segment ring or invert section shall only be formally accepted when it fulfills all structural, geometric, and material performance parameters detailed below:

(i) Mechanical Strength Performance

- **Hardened Grout Matrix:** The characteristic compressive strength of the primary backfill grout shall be **≥ 25 MPa at 28 days**, as verified by the laboratory crush tests.
- **Hardened Invert Mortar:** The characteristic compressive strength of the invert leveling mortar shall be **≥ 25 MPa at 28 days**. The surface must show zero evidence of structural cracking, micro-fissures, or spalling under early rolling-stock traffic.

(ii) Volumetric Integrity & Void Mitigation

- **Total Annular Void Filling:** The backfill operation must achieve **100% volumetric filling** of the structural tail void between the segment ring and the excavated ground profile. The total volume injected per ring must meet or exceed the theoretical calculated annular space volume (accounting for overcutting tolerances).
- **Non-Destructive Validation (NDT):** The complete absence of voids or empty water pockets at the tunnel crown shall be verified using approved non-destructive methods (such as Ground Penetrating Radar / GPR scanning or systematic physical verification through the segment grout ports). Any identified localized void formations shall be immediately re-grouted via secondary injection.

(8) Injection Pressure Management

- **Pressure Limits:** Backfill injection pressures must be maintained strictly within the design envelope specified by the tunnel engineer (e.g., matching or slightly exceeding the external hydrostatic and ground pressures).
- **Structural Protection:** The maximum injection pressure shall never exceed the maximum structural safe load limit of the precast concrete segment faces or the structural tolerances of the TBM tail skin elastomeric wire-brush seals. Over-pressurization that threatens to damage the segment gaskets or distort the ring geometry shall trigger an immediate automated safety shutdown of the TBM injection pumps.

(9) Measurement and Payment

- Measured per m^3 of grout or mortar placed.
- Pea gravel measured per m^3.
- Rates include supply, transport, placement, injection, testing, and records.

1830 TBM-Mounted Drilling Works for Various Purposes

(1) Scope of Work

This specification covers the technical requirements for **all drilling operations** conducted from or within the Tunnel Boring Machine (TBM). This includes systematic advance probe holes, holes for pre-excavation or chemical grouting, drainage hole installation, and drilling required for forepoling and umbrella pipe roofing systems. All operations shall be executed to the designated line, grade, and angle in compliance with project specifications and the directions of the Engineer.

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(2) Applicable Reference Standards

Drilling equipment alignment, execution protocols, and ground investigation parameters shall generally align with:

- **ITA Guidelines:** Guidelines for the Design of Tunnels / Guidelines for the Selection of Tunnel Support Systems.

(3) General Requirements for TBM Drilling Equipment

- **TBM Integration:** Drilling operations shall be executed utilizing the dedicated, high-capacity drilling arrangements mounted directly on the TBM structure.
- **Capacity & Spacing:** The mechanical configuration of the drilling rigs must allow for a sufficient number of drill holes to be completed comfortably at the spatial density and breakout angles required for grouting, umbrella pipe roofing, or forepoling.
- **Operational Windows:** The Contractor shall make all necessary logistical arrangements to carry out drilling systematically during scheduled maintenance hours, as well as during TBM operation hours when instructed by the Engineer.

(4) Technical Parameters for Drilling Operations

All drill holes executed under this specification must conform to the following explicit geometric and technical metrics:

- **Minimum Hole Diameter: 75 mm** (unless a larger diameter is explicitly required to clear drainage pipes, forepoles, or umbrella pipes).
- **Standard Hole Length:** Generally **30 meters**, or as dynamically adjusted by the direct instruction of the Engineer.
- **Sequential Overlap:** A minimum overlap of **5 meters** must be maintained between successive cycles of systematic probe drilling to prevent unmapped zones ahead of the face.
- **Inclination / Alignment:** Holes shall be drilled outward from the tunnel boundary at an inclination angle bounded between **7° and 10° relative to the main tunnel axis**, or true to the engineered design lines for support canopies.
- **Drilling Fluids and Lubricants:** Lubricants and drilling flush fluids used must be chemically formulated and applied such that they **do not partially or fully clog the hole**. The fluid must not degrade, alter, or wash out the drill cuttings, rendering them unidentifiable for geological profiling and mapping.

(5) Documentation and Logging

- The drilling process for every hole shall be meticulously documented in standard proforma/log formats approved by the Engineer.
- Logs must capture penetration rates, water/flush loss or inflows, structural changes, and the exact characteristics of the recovered cuttings to map the rock and hydro-geological profile ahead.

(6) Quality Control and Validation Criteria

- **Verification:** Only drill holes executed in strict compliance with the approved procedure, sequence, alignment, and depth shall be measured for validation.
- **Failed Holes:** Any hole drilled without following the approved procedure, or holes that do not yield actionable geotechnical/hydro-geological information due to technical errors, operational negligence, or improper fluid usage, shall be classified as a **failed hole**. Failed holes shall be excluded from all performance records and shall not be accounted for payment.

(7) Measurement and Payment

- **Unit of Measurement:** Validated drill holes for any of the aforementioned purposes shall be measured exclusively by the actual length drilled in **running meters**.

- **BOQ Item Reference:** Payment shall be made as per the quoted rate in **the Bill of Quantities (BOQ)** based on the validated running meter quantities.
- **Rate Inclusivity:** The unit price per running meter shall be deemed to include full compensation for all associated operational costs, including specialized human resources, TBM-integrated or auxiliary drilling rigs, drill bits, casing management, non-clogging lubricants, flushing agents, and all sundries required to execute the drilling works smoothly as per the approved procedure.

1831 GROUND STABILIZATION by Fore-poling and Umbrella Pipe Roofing (TBM Operations)

(1) Scope of Work

This specification defines the rigorous technical protocols for the design proposal, material verification, execution, quality control, and measurement metrics for Ground Stabilization by Fore-poling and Umbrella Pipe Roofing implemented from the Tunnel Boring Machine (TBM). These measures are designed to provide pre-stabilization, prevent crown/face breakouts, or mitigate face collapse during excavation in unstable geological zones before the structural segmental lining is systematically erected and back-grouted.

(2) Technical Proposals and Approval Mechanism

- **Trigger Criteria:** When advance probe drilling, Horizontal Seismic Profiling (HSP), geodetic convergence data, real-time TBM parameter monitoring, or direct geological mapping at the face/shield indicators reveal unstable rock mass zones requiring pre-stabilization, the Contractor must formally initiate a ground stabilization proposal.
- **Submission Requirements:** For each individual stretch requiring support, the Contractor shall submit a detailed engineering proposal to the Engineer for approval. This submittal must include:
    - A thorough analysis of the site-specific ground conditions and the technical justification for selecting the chosen stabilization method.
    - Complete structural designs, cross-sectional layouts, material properties, and engineering properties of the proposed poles/pipes.
    - Detailed drawings outlining the longitudinal spacing, breakout angles, structural overlaps, and layout configurations over the TBM shield/crown area.
    - A comprehensive operational method statement, including deployment schedules, handling procedures, and a list of specific installation equipment mounted on the TBM.
- **Execution Authorization:** The Contractor shall execute the stabilization works strictly in accordance with the proposal approved by the Engineer, with or without modifications.

(3) Material and Geometric Baseline Requirements

The Contractor shall satisfy the following minimum dimensions and material rules unless a superior alternative is engineering-justified and formally approved by the Engineer:

- **Drilling Diameter:** Not less than **55 mm** in diameter.
- **Pipe Stabilization Option:** High-strength steel canopy pipes with an outer diameter of not less than **48 mm**.
- **Reinforcement Bar Option:** Solid high-yield deformed structural steel reinforcement bars/rods with a minimum diameter of **32 mm** may be substituted where geotechnically appropriate.
- **Spatial Coverage:** Fore-poling and umbrella pipe roofing arrays shall be systematically mapped and installed across the tunnel crown and/or side walls as required by the localized ground structure.

(4) Engineering Design and Structural Mechanics

- **Structural Model:** Fore-poles and umbrella pipes shall be designed to function as a continuous longitudinal structural beam providing advance canopy support. The mechanical design must assume that one end of the beam is structurally anchored and supported by the previously erected segmental lining, while the leading end is embedded in and supported by the intact ground ahead of the TBM excavation face.
- **Design Load and Span:** The structural calculations for bending, shear, and buckling limits of the poles/pipes shall be based on an assumed design span equal to **1.5 times the unsupported length** of the tunnel excavation step. Design loading parameters must incorporate site-specific, worst-case rock mass classification data.
- **Structural Overlap:** The sequential longitudinal overlap length between consecutive canopy umbrellas must be structurally engineered to fully bridge and cover a potential ground collapse zone evaluated at approximately **45°**.

(5) Drilling and Installation Methodology

- **Drilling Alignment:** All umbrella and fore-pole holes must be drilled true to design lines, maintaining an inclination angle bounded strictly between **7° and 10° relative to the main tunnel axis**.
- **Drilling Equipment:** Drilling shall be executed utilizing dedicated rotary or percussion drilling systems integrated and mounted directly onto the TBM frame architecture.
- **Stabilization Grouting:** To achieve rigid bonding and fill the annular space within the rock mass, pressure grouting of the fore-pole or umbrella canopy pipes shall be executed. Depending on the immediate structural stability requirements dictated by the ground type, grouting operations shall be conducted **concurrently with, immediately after, or even prior to** the final mechanical positioning of the poles as designated by the Engineer.

(6) Quality Control and Validation Criteria

- **Installation Integrity:** Fore-poles and umbrella canopies must be structurally intact and successfully preserved throughout the TBM excavation cycle until the permanent concrete segmental lining is erected, the annular space is filled with pea gravel, and backfill grouting is structurally finalized.
- **Failed Installations:** Any drilled hole where a fore-pole or umbrella pipe cannot be successfully installed, or arrays that are structurally damaged due to improper execution or TBM shield clearance issues, shall be classified as **failed holes**. These will be excluded from all measurement registers.

(7) Measurement and Payment

(i) Unit of Measurement

- The ground stabilization support works shall be quantified and measured strictly by the actual length in **running meters** of valid fore-pole reinforcement rods or steel pipes successfully installed and verified in place, explicitly including the designated engineering overlap lengths.

(ii) Performance Restrictions

- Linear payment validation shall be restricted exclusively to the specific lengths of fore-poling or umbrella pipe roofing that have been correctly positioned, fully grouted (where required), and successfully preserved without displacement until the concurrent activity of permanent segment lining installation is completed.

(iii) Bill of Quantities (BOQ) Reference

- Payment for validated quantities shall be made at the quoted unit price per running meter **in the Bill of Quantities**.

(iv) Inclusivity of Unit Rate

The contracted unit price per running meter shall constitute full and complete compensation to the Contractor for all operational and material input costs, encompassing:

- Furnishing, quality-testing, workshop handling, fabrication, and site-positioning of all steel pipes, reinforcement bars, and structural canopy components.
- All labor, materials, water management, and specialized machinery inputs required for TBM-mounted drilling, borehole alignment verification, and post-drilling borehole washing.
- All integrated attachments, couplings, structural accessories, end caps, and temporary anchoring supports.
- Provision and installation of pressure relief valves, specialized packers, and any incidental materials necessary to complete the rigid erection, grouting, and structural preservation of the fore-poling and umbrella roofing system to the satisfaction of the Engineer.

1832 SUBSURFACE DRAINAGE PIPE INSTALLATION (TBM Operations)

(1) Scope of Work

This specification defines the rigorous technical protocols for the design proposal, material verification, execution, quality control, and measurement metrics for the **Installation of Subsurface Drainage Pipes** implemented from the Tunnel Boring Machine (TBM). These measures are designed to intercept and drain subsurface water ahead of or around the TBM shield, keeping the excavation surface free of flowing water until the permanent segmental lining is systematically erected and finalized.

(2) Technical Proposals and Approval Mechanism

- **Trigger Criteria:** When advance probe drilling, hydro-geological mapping, or real-time TBM operational parameters indicate heavy water ingress, high-pressure aquifers, or unstable ground conditions aggravated by subsurface water, the Contractor must formally initiate a drainage proposal.
- **Submission Requirements:** For each individual tunnel stretch requiring water control, the Contractor shall submit a detailed subsurface drainage mechanism proposal to the Engineer for approval. This submittal must include:
    - A technical justification outlining the hydrology and the anticipated ground behavior under water load.
    - Complete structural designs, dimensioned engineering drawings, and material properties of the drainage pipes and filtering media.
    - Detailed layouts showing the spatial density, longitudinal intervals, and breakout angles of the drainage holes over the TBM shield/body.
    - A comprehensive operational method statement, including handling procedures, execution schedules, and a list of specific installation equipment mounted on the TBM.
- **Execution Authorization:** The Contractor shall execute the drainage pipe installation works strictly in accordance with the proposal approved by the Engineer, with or without modifications.

(3) Material and Geometric Baseline Requirements

The Contractor shall satisfy the following minimum dimensions and material rules unless a superior alternative is engineering-justified and formally approved by the Engineer:

- **Drilling Diameter:** Not less than **55 mm** in diameter.
- **Drainage Pipe Diameter:** Not less than **35 mm** outer diameter.
- **Pipe Configuration:** In cases where the drainage hole requires mechanical protection against immediate wall collapse or clogging, **perforated Polyvinyl Chloride (PVC)** or **steel drainage pipes** with a minimum diameter of **35 mm** must be used.
- **Filtration Wrapping:** To prevent the migration of fines and subsequent clogging of the perforations, the drainage pipes must be wrapped securely in a **geotextile filter fabric** featuring sufficient lapping and robust attachment.

(4) Drilling and Installation Methodology

- **Drilling Alignment:** All drainage holes must be drilled true to design lines, maintaining an inclination angle bounded strictly between **7° and 10° relative to the main tunnel axis**.
- **Drilling Equipment:** Drilling shall be executed utilizing dedicated rotary or percussion drilling systems integrated and mounted directly onto the TBM frame architecture.
- **Immediate Deployment:** To maintain a dry and safe working environment at the face, the specified drainage pipes must be inserted immediately following hole completion and securely fixed in place to ensure instant, high-efficiency evacuation of subsurface water.

(5) Quality Control and Validation Criteria

- **Installation Integrity:** Drainage pipes must be functionally active, structurally intact, and successfully preserved throughout the TBM excavation cycle until the permanent concrete segmental lining is erected.
- **Failed Installations:** Any drilled hole where a drainage pipe cannot be successfully installed, or arrays that are crushed, blocked, or structurally damaged due to TBM operational movements, shall be classified as **failed holes**. These will be excluded from all measurement registers.

(6) Measurement and Payment

(i) Unit of Measurement

- The drainage pipe installation works shall be quantified and measured strictly by the actual length in **running meters** of valid drainage pipe/hole successfully installed and verified in place.

(ii) Performance Restrictions

- Linear payment validation shall be restricted exclusively to the specific lengths of drainage pipe that have been correctly positioned, wrapped, and successfully preserved without displacement until the concurrent activity of permanent segment lining installation is completed. No measurement will be granted for unprotected holes that collapse prior to pipe insertion.

(iii) Bill of Quantities (BOQ) Reference

Payment for validated quantities shall be made at the quoted unit price per running meter in the Bill of Quantities.

6.4 Inclusivity of Unit Rate

The contracted unit price per running meter shall constitute full and complete compensation to the Contractor for all operational and material input costs, encompassing:

- Furnishing, handling, cutting, perforating, and workshop preparation of all PVC or steel drainage pipes.
- Supply, tailoring, lapping, and wrapping of the geotextile filter fabric around the pipe exterior.
- All labor, materials, water management, and specialized machinery inputs required for TBM-mounted drilling, alignment verification, and post-drilling borehole washing.
- All integrated attachments, couplings, specialized end caps, structural accessories, and temporary anchoring anchors.
- Provision and installation of pressure relief valves, specialized packers, drainage manifold adaptors, and any incidental materials necessary to complete the rigid erection, operational preservation, and completion of the subsurface drainage work. No separate or additional payment shall be made thereof.

1833 COMPLIANCE MAPPING TABLE

Specification Clause	Aligned Standard / Report No.	Reference / Notes
1802 General Requirements (Safety, ventilation, portals, communications, records)	JSCE 2006 Ch. 3 Safety; JRA Road Tunnel Safety Provisions	Ventilation rates, PPE, lighting levels per JSCE; portal stabilization per JRA
1803 Drill & Blast Excavation	JSCE 2006 Sec. 4 Excavation; NEXCO Sec. 3.3; JRA Blasting Guidelines	Probe drilling length/diameter per JSCE; smooth blasting near portals per JRA
1810 Steel Rib	JSCE 2006 Sec. 5 Support; JRA Structural Division; NEXCO Sec. 3.4	Steel grade SS400/SM490 per JIS; rib spacing 0.75–1.5 m per JSCE
1811 Shotcrete	JSCE 2006 Sec. 6 Shotcrete; JRA Shotcrete Standards; NEXCO Sec. 3.5	Mix design cement ≥400 kg/m³; fibre dosage 40–60 kg/m³; testing frequency per JSCE
1812 Rock Bolt	JSCE 2006 Sec. 7 Rock Bolts; JRA Bolt Standards; NEXCO Sec. 3.6	Bolt diameter 25–32 mm; pull-out test frequency 1 per 50 bolts per JSCE
1813 Portal Works (Drill & Blast)	JRA Portal Excavation Standards; NEXCO Portal Design	Controlled blasting, slope stabilization, drainage per JRA
1818 TBM Excavation	ITA WG14 / WG19	1818 TBM Excavation
(Mechanized Tunnelling / Conventional & Deep Tunnels)	Controls advance rates, face support calculations, and exceptional structural geology procedures. ICOLD Bulletin 88 provides secondary case-history reference for heavy hydraulic ground interactions.	(Mechanized Tunnelling / Conventional & Deep Tunnels)
1828 Segment Lining (TBM)	ITA WG2 Report No. 22 (2019)	1828 Segment Lining (TBM)
Guidelines for the Design of Segmental Linings	Dictates Concrete Grade C50/60 durability profiles, tight structural manufacturing/erection tolerances (±5 mm radial), and specialized elastomeric gasket hydro-compression testing.	Guidelines for the Design of Segmental Linings
1829 Annular Backfill & Grouting (TBM)	ITA WG2 Report	1829 Annular Backfill & Grouting (TBM)
(Section on Tail Void Injection Methods)	Specifies 4–8 mm pea gravel and stable structural 0.5:1 w/c grout mixes. Restricts transient injection loading to ≤10 bar to prevent rings from distorting or shifting during TBM advancement.	(Section on Tail Void Injection Methods)
1820 TBM Consumables & Cutter Management	ITA WG14 Tech Paper / WG19	1820TBM Consumables & Cutter Management

1834 IMPLEMENTATION NOTES

- **Drill & Blast**: All mixes, bolt diameters, and testing frequencies are directly aligned to JSCE 2006 Mountain Tunnels, with cross-checks against NEXCO and JRA for road tunnel specifics.
- **TBM**: Segment lining, annular backfill, cutter consumption, and maintenance schedules follow ITA guidelines and ICOLD bulletins (79, 88).
- **Annexes**: Cutter consumption and TBM cost tables are structured per ITA recommendations.
- **Forms**: Grout logs, ring acceptance checklists, and cutter replacement records are included for audit compliance.

1835 ANNEXES

Annex Table 1 Cutter Consumption in TBM Tunnelling

Cutter Type	Nominal Diameter mm	Expected Life (m advance)	Replacement Frequency per 100 m	Remarks
Disc cutter (hardened steel)	350	1,200	0.08	Medium–hard rock; life varies with abrasivity
Disc cutter (tungsten carbide tipped)	400	800	0.125	Mixed abrasive conditions; higher cost
Button cutter (carbide)	120	400	0.25	High wear in abrasive zones; keep spares on site
Scraper / drag cutter	200	600	0.167	For soft to medium rock; sensitive to inclusions
Mixed cutter set average	—	500	0.20	Use as baseline; update from site logs

Annex Table 2 Indicative Cost Breakdown for TBM Works

Cost Item	Unit	Indicative Value (USD)	Basis / Notes
TBM capital allocation	Lump sum		Purchase, transport, insurance amortized over contract
Mobilisation and demobilisation	Lump sum		Assembly, commissioning, retrieval and transport
Operation cost	USD / m		Power, crew, routine consumables
Maintenance and overhauls	USD / m		Scheduled maintenance and major replacements
Consumables	USD / m		Cutters, seals, grout, gaskets
Spare parts contingency	% of capital		On-site inventory value for critical spares
Total indicative cost per metre	USD / m		Operation + maintenance + consumables for planning

Grout Injection Log Template

Project	Tunnel / Ring No	Date	Contractor
Grout Hole ID	Hole Depth m	Packer Zone	Packer Depth From-To m
Grout Mix ID	Water:Cement Ratio	Grout Volume Injected L	Injection Pressure bar
Start Time	End Time	Grout Take L/min	Remarks / Observations
Operator Name	Witness (Engineer)	Signature Operator	Signature Engineer

Use instructions

- *Fill one row per packer zone or injection interval. Record cumulative volumes per hole and per ring. Attach grout mix design and batch numbers.*

Ring Acceptance Checklist Template

Project	Tunnel Chainage	Ring Number	Date
Segment Batch No	Segment Concrete Grade	Gasket Type / Batch	Erected By (crew)
Ring Geometry Radial mm	Ring Geometry Axial mm	Max Deviation Allowed mm	Measured By
Gasket Seating OK	Bolt Torque Nm	Bolt Torque Verified By	Grout Injected L
Annular Backfill Type	Backfill Volume L	Leak Test Result	Remarks / Defects
Acceptance Status	Accepted By (Engineer)	Date	Corrective Actions Required

Use instructions:

- *Complete measurements immediately after ring erection. Record any remedial works and re-inspection dates. Keep checklist with ring records.*

Cutter Replacement Record Template

Project	Tunnel Chainage	Date	TBM ID
Cutter Position ID	Cutter Type	Nominal Dia mm	Cutter Serial / Batch
Life at Removal m	Reason for Replacement	New Cutter Serial	New Cutter Installed By
Replacement Time Start	Replacement Time End	Downtime min	Remarks
Operator Name	Maintenance Supervisor	Signature Operator	Signature Supervisor

Use instructions:

- Log every cutter change. Use cumulative life to update cutter consumption table and forecast spares.

SECTION 1900 – CANAL LINING WORKS

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1901 SCOPE

This Section comprises general requirements for the works related to the canal lining such as lining using different materials, laying filter layers, joints filling and sealing, drainage arrangement works, etc.

1902 GENERAL

Canals are lined to reduce seepage losses, and to reduce the chances of waterlogging in a given area. Various types of lining options are available such as concrete, tiles, slate, brick block, concrete mattress, precast slab and soil cement lining, and the selection of a particular type of lining is related to its cost effectiveness, site suitability and availability. Lined channels are non-erodible, and hence their design theories are different from those of unlined canals.

1903 CANAL LINING BY CEMENT CONCRETE

(1) Scope

This Clause covers the thickness, grade, hauling distance and lifting height of cement concrete. It also includes the method of applying concrete as well as lining of concrete. Slope of the canal shall be checked by the engineer before applying the concrete. Concrete lining for canals is recommended only where the cost is justified over other types of lining.

(2) Materials

Materials required for the Concrete lining works such as Cement, Sand, Aggregates and Water shall be in accordance with clause 803. The concrete used for lining should be design mix concrete of grade M10 or M15 and should conform to requirement of IS 456:2000. In case of use of Geotextile, Clause 1504 shall be referred. The lining can be placed by machines or laid manually.

(3) Construction

The subgrade shall be prepared, dressed and rolled true to level and according to the required cross-section of the canal to form a firm compacted subgrade for the lining. For checking the uniformity of side slopes, sample profiles at an interval of about 20 m, in straight reaches and 10 m in curved reaches shall be made. Excavated profile provides the final base for the lining and the tolerance should be comparable to those required for paving.

The thickness varies from 5 to 15cm. The banks are dressed to a self-supporting slope of 1.5 (H): 1 (V) to 1.25 (H): 1 (V). Where the slopes are steeper than this, the thickness of the concrete lining increases steeply rendering it uneconomical. The thickness of lining depends on the requirements of impermeability and structural strength necessary to avoid cracking with minor movement of the subgrade. Concrete should not be dropped from excessive height and free fall should be kept to a minimum to avoid segregation. Construction should be continued until satisfactory construction joint is made. Concrete should not be placed faster than the placing crew can compact it properly.

The surface of concrete finished against forms should be smooth, even, free from projections, honeycombing and other objectionable defects. Immediately on the removal of forms, all unsightly ridges or lips should be removed and undesirable local bulging on exposed surfaces should be remedied by tooling and rubbing. Repairs to concrete surfaces and additions, where required, should be made by cutting regular openings into the concrete and placing fresh concrete to the required lines.

Subsequent to laying of concrete lining and after a period of 12 hours, the lining should be cured for at least 28 days. Water should be continuously sprinkled on the gunny bags or hessian cloth keeping them wet for 28 days.

IS 3873:1993 shall be followed for the manual and mechanical laying, details of laying, placing and compaction

process of construction method.

(4) Tolerance in Concrete Thickness, Alignment and Grade

(a)	Departure from established alignment	- ± 20 mm on straight reaches
		- ± 50 mm on partial curves or tangents
(b)	Departure from established grade	- ± 20 film on small canals
(c)	Variation in concrete lining thickness	- ± 10 mm provided average thickness is not less than specified thickness

(5) Construction Joints in Concrete Lining

Construction Joints which also exhibit as contraction and expansion joints shall be spaced at an interval of 12m shall be formed in plastic concrete. The Contractor shall demonstrate to the Engineer 's satisfaction that a surface finish across the joints is obtainable within the appropriate tolerances as specified.

The contractor shall ensure that the spacing and layout of the joints is arranged so that the joint face of the concrete lining is uniform with smooth face and spaced in regular intervals as shown in the drawing or as directed by the engineer. The progress of lining work shall be made in alternate panels or continuous as approved by the engineer after demonstration of sample lining stretch. The joint gaps shall be filled with 10mm thick filler of approved material and next concrete shall be poured on adjacent panels. The exposed gap on the surface shall be subsequently sealed with approved with sealing material.

(6) Method of lining

The method of lining shall be selected according to the availability of resources and overall cost of project. Skilled manpower shall be appointed to operate machine used in canal lining.

(a) By mechanical means

Concrete mix proportions such as cement, sand, aggregate and water shall be calculated by engineer before supplying to the mixer. Trained manpower shall be appointed by the contractor to operate the machines. Concrete vibrators operate at high frequencies, typically ranging from 10,000 to 15,000 vibrations per minute (VPM). The high frequency helps in achieving proper consolidation of the concrete, eliminating air voids, and enhancing the overall quality and durability of the lining. Either drum type mixture or specified by engineer shall be used.

(b) By manual means

For small project or project situated in hilly area shall be completed by manual means. Proportion of materials shall be checked by site engineer before mixing.

(c) By paving machine

Before the paving process begins, the canal bed shall properly be prepared by excavating and compacting the soil to create a smooth and stable foundation for the lining.

The paving machine shall be equipped with a hopper or a receiving container that holds the concrete or asphalt mixture. This material is typically supplied by concrete mixer trucks or asphalt plants located nearby.

The machine moves forward along the length of the canal while continuously depositing the concrete or asphalt mixture onto the prepared canal bed. The distribution mechanism may have adjustable width and thickness settings to control the dimensions of the lining.

(7) Test and Standard of Acceptance

Test and standard of acceptance for concrete lining work shall be in accordance with IS 3873:1993.

(8) Measurement and Payment

The measurement of the concrete lining of required thickness shall be in Sq.m.

Payment for the concrete lining works shall be made as per contract unit rate as specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1904 BOULDER PITCHING IN CEMENT SAND MORTAR

(1) Scope

This Clause covers the design and laying of boulder/stone masonry lining for canals bed and slopes.

(2) Materials

Materials required for the boulder/stone masonry lining works such as Cement, Sand, Aggregates and Water shall be in accordance with clause 803. The mortar used for lining should be of 1:3 or 1:4 and should conform to requirement of Clause 602 of Section 600. Boulders shall be in accordance with IS 4515:2002, IS 1126:1974 and IS 10430:2000.

(3) Construction

The sub-grade should be prepared according to IS 3873.

The stones should be of dimensions mentioned in Table 19.1 and should have specific gravity not less than 2.5 when tested according to IS 1122 : 1974 and soundness not less than 10% loss of weight after 5 cycles when tested according to IS 1126 : 1974. The stone shall be laid on cement mortar 1: 3 or 1:4 over a bed of minimum 12 mm thick cement mortar. The joints shall be pointed with similar mortar.

The lining shall be started after at least 35 m length of canal sub-grade is properly dressed to receive lining. The subgrade shall be uniformly soaked with water, without making it slushy, to ensure that water penetrates to a depth of about 300 mm in sandy soil and about 150 mm in other soils. Wetting of subgrade shall be continued in advance of laying of stone so that the soil does not absorb moisture from the mortar placed on the subgrade for laying of stone masonry layer. If the water table is high, it should be lowered to at least 300 mm below the subgrade.

The subgrade shall be divided into compartments by stone masonry or concrete ribs of size not less than 300 mm X 150 mm. The compartments shall have dimensions of not more than 15 m along the centre line of the canal. The spacing of ribs across the centre line shall be selected in such a manner so as to divide the canal bed and slope symmetrically about the centre line, so that ribs are provided at the junction of the slope and bed and at the upper extremity of the slope. If stone masonry ribs are used, the stone should meet the requirements given above.

Pressure relief arrangements should be done drainage of lined canals according to IS ; 4558 : 1983.

Single stone profiles of lining, parallel to centre line of the canal, should be prepared at suitable intervals. Mortar should be uniformly spread over the subgrade and the stone should be properly laid in position quickly. It should be ensured that the vertical joints are completely filled with mortar. The stone should be laid on the bed with their length at right angles to the centre line of the canal, while on the side slopes, they should be laid parallel to the centre line.

One completion of laying and from the next day, the lining should be kept wet by sprinkling water over it, to keep the mortar well wetted. On the next day, the surface should be kept wet and joints of the stone masonry should be carefully tested. Hollow joints should be raked to a depth of 12 mm, loose mortar removed from sides and top of stone and the joints should be removed and re-laid.

The completed lining should be checked for levels with wooden templates and spirit levels.

Table 19.1: Dimensions of stone and Thickness of lining

S.N	Canal capacity (cumecs)	Thickness of lining (mm)	Average dimension along the longest axis. (mm)	Minimum dimension at any section (mm)
1	0 to less than 10	150	150	75
2	10 to less than 100	225	225	110
3	100 and above	300	300	150
NOTE – Tolerance up to percent in permissible in the thickness of lining and the dimensions of stones.				

(4) Measurement and Payment

The measurement of the boulder pitching in cement sand mortar of required thickness shall be in Sq.m.

Payment for the dry boulder pitching works shall be made as per contract unit rate as specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1905 DRY BOULDER PITCHING IN FILTER AGGREGATES

(1) Scope

This Clause covers the design and laying of dry boulder/stone pitched lining for canals bed and slopes.

(2) Materials

Materials required for the boulder pitching works such as boulders and aggregates shall be in accordance with IS 4515:2002, IS 456:1978, IS 1126:1974 and IS 10430:2000.

Stones used for lining shall be rounded or sub angular river cobbles or blasted rock pieces with sufficient base area to be stable. All the stones shall have a reasonably uniform size with dimensions as given in Table 19.2, depending upon the canal capacity.

Table 19.2Dimensions of Stones and Thickness of Lining

SN	Canal Capacity (m3/s)	Thickness of Lining (mm)	Average Dimension along the largest axis (mm)
1	0 to less than 10	150	150
2	10 to less than 100	225	225
3	100 and above	300	300

NOTES

1. Maximum tolerance of 10 percentage permissible in the thickness of lining and the dimensions of stones.

2. Limiting safe velocity may be adopted as 1.5m/s.

Individual stones should be sound, hard and durable and should be such that they will be able to sustain weathering and water action. They should be free from laminations, soft spots, cracks, seams and other

defects. The help of tests and requirements given in Table 19.3 for stones may be taken in making a judgement of the suitability of stones for canal lining.

Table 19.3 Requirements for Stones

SN	Test	Requirements
1	Specific (apparent) gravity when tested according to the method given in IS 1126	Greater than 2.5
2	Soundness (sodium sulphate method) when tested according to IS 1126	Less than 10 percent loss of weight after 5 cycles

(3) Construction

The sub-grade should be prepared according to IS 3873.

Sub-grade (both bed and slope) of the canal should be divided into compartments by stone masonry or concrete ribs. The compartments should have dimensions of not more than 15 m along the length of the canal. The spacing of ribs cross in the section of the canal should be so chosen as to divide the canal bed and slope symmetrically about the centre line and in such a manner that ribs are provided at the junction of the slope and bed and at the upper extremity of the slope. The ribs along the slope of the bank should be continuous.

A 15 cm thick layer of filter material is required and should be laid in compartments formed by ribs. Filter material should be in accordance with requirements specified in (4) below.

Stones should be carefully hand packed in the compartments. The placing method should be such as to ensure a reasonably smooth surface and uniform thickness. Spaces between the stones should be minimized. Such spaces should be wedged with spans of suitable size to avoid filter material being washed out. Such filling should immediately follow the placing of stones.

(4) Filter

Filter material should be free from flakes, soft particles, shale, organic matter or other deleterious substances. Filter should satisfy the criteria:

$$\text{i)} \quad \frac{D_{15}\ (\text{Filter})}{D_{15}\ (\text{Base})} > 4 < 40$$

$$\text{ii)} \quad \frac{D_{15}\ (\text{Filter})}{D_{85}\ (\text{Base})} < 5$$

Where a large difference exists between the grading of the free draining material and of the soil to be retained, it may be necessary to use more than one layer of filter material, each progressively larger in grain size and satisfying the filter criteria. The design of granular filter, selection of material, thickness of layer, number of layers and construction of filter shall be in accordance to IS 4515:2000. The sub-grade, before placing the filter, shall be firm and compacted suitably. Clean filter material shall have sufficient water content (3 to 10 percent) during placement and placement shall be such that segregation is prevented.

(5) Measurement and Payment

The measurement of the dry boulder pitching of required thickness shall be in Sq.m.

Payment for the dry boulder pitching works shall be made as per contract unit rate as specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1906 BRUNT CLAY TILE LINING

(1) Scope

This Clause covers the laying of brunt clay tile lining for canals bed and slopes.

(2) Materials

Cement conforming to IS 269 or IS 455 or IS 1489 (Part 1) or IS 1489 (Part 2) or IS 8112 or IS 12269 as specified by the engineer-in-charge.

Sand conforming to IS 2116 or IS 1542 as specified by the engineer-in-charge.

Water used for both mixing the mortar and curing shall be conform to the requirements specified in IS 456.

Tiles Conforming to IS 2116 or IS 1542 as specified by the engineer-in-charge. The tiles shall be made from suitable soil of even texture and shall be uniformly well burnt. They shall be uniform in size, shape and free from irregularities, such as cracks and laminations. The tiles shall be free from impurities like particles of stone, lime and other foreign materials visible to the naked eye on the surface or on the fractured surface of the tiles obtained by breaking the sample. The physical properties like compressive strength, transverse strength, water absorption and maximum wrap shall be in accordance to IS 3367:1993.

(3) Dimension

The size of the tile shall be 300 X 150 X 50 mm. The permissible tolerance on the dimensions of the tile shall be ±10 mm in length, ±5 mm in width and ±1.5 mm in thickness. There shall be no frog in the tile.

(4) Design Consideration

The lining may consist of single tile lining or double tile lining as specified. Single tile lining shall consist of single layer of burnt clay tiles laid on about 10 mm thick 1:5 cement mortar on the well-dressed subgrade. Joints shall be well filled with mortar of the same consistency. Joints shall then be raked to 12mm depth, and after that not less than 20 mm thick cement plaster 1: 3 shall be laid on it, which shall be given smooth finish. The mortar shall be laid on 6 m lengths; the lengths being laid alternately. The total thickness of lining shall be not less than 80 mm. The thickness of joints shall not exceed 10mm. Double tile lining shall consist of double layer of tiles with a sandwiched layer of cement mortar 1:3.

The sides shall consist of double layer of tiles with not less than 15 mm thick sandwiched layer of cement mortar of 1: 3 mix. The first layer of tiles shall be laid on about 10 mm thick 1: 5 cement mortar spread on compacted subgrade dressed to specified slope. The joints shall be filled with mortar of the same consistency. The first layer of tiles shall be covered with 1: 3 cement plaster not less than 10 mm thick on the top of which second layer of tiles shall be laid in about 16 mm thick 1: 3 cement mortar except for the bottom one meter length before its junction with single tile lining in the bed. The last meter in such case shall be joined to the single tile lining in the bed by laying 1: 2: 4 cement concrete in half meter width and by laying 1: 3 cement mortar in the rest half. Total thickness of lining masonry shall be not less than 130 mm. The thickness of joints shall not exceed 10 mm.

The proportions for cement mortar used for lining works shall conform to IS 3872:2002 and IS 2250. The use of admixtures, including waterproofing compounds may be permitted if approved by the engineer or mentioned in the contract.

(5) Top Coping

To check the leakage of rainwater behind the lining in sides, not less than 150 mm thick cement concrete coping of Grade M-I0 conforming to IS 456 or of a double layer of tiles with a mortar mix specified for slopes shall be provided horizontally on the top of the lining. The width of the coping at the top shall not be less than 350 mm.

(6) Preliminary works

Humps of concrete or masonry about 150 mm high shall be provided where necessary in the bed of the canal at every 300 m intervals, to ensure that during short closures the bed of the canal does not dry and thus does not expose the plaster to direct rays of sun which may otherwise result in formulation of cracks.

Tiles shall be properly soaked in water for at least four hours are available for carrying out the work during each day.

(7) Laying Of Tiles

- Laying of first Layer or Tiles - First and Second Day

The subgrade shall be prepared, compacted and treated in accordance to clause 6 of IS 3872:2002. The lining shall be started only when at least 35m length of canal with subgrade is properly dressed to receive lining. Where spring level is high the water table shall be lowered to at least 30 cm below the subgrade by dewatering.

The subgrade shall then be uniformly soaked with water without making it slushy to ensure that water penetrates to a depth to about 300mm in sandy soil and about 150 mm in other soils. Wetting of subgrade shall continue in advance of laying of tiles so that the soil does not absorb moisture from 10mm thick mortar laid on the subgrade for laying the layer of tiles.

Single tile profiles of lining parallel to centre line of the canal shall be prepared at suitable intervals. Mortar shall be uniformly spread over the subgrade and the tiles shall be properly laid in position quickly after that. Care shall be taken to see that the vertical joints are completely filled with mortar. The tiles shall be laid in bed at right angles to the centre line of the canal while on the side slopes they shall be laid parallel to the centre line.

Enough number of profiles both in the bed and slopes shall be laid each day so that when the work is started next day the marks shall already be in position. Construction points or panels at suitable width each in bed and sides shall be perfectly rolled, levelled and laid with profiles every day to receive lining of the first layer of tiles on the next day.

Tiles shall be firmly embedded in mortar. Hollows, if any, shall be rectified by relaying the defective portions with fresh mortar.

- Curing and Correction - Third and Fourth day

On the third day layer of tile shall be kept wet by sprinkling water over it, to keep the mortar well wetted. On the fourth day, the surface shall be kept wet and joints of the tile masonry shall be carefully tested. Hollow joints shall be raked to a depth of 12 mm, loose mortar removed from sides and top of tiles and the joints properly refilled. Any loose tile shall be removed and re-laid.

- Laying Cement Mortar Layer - Fifth Day

For Single Tile Lining

Not less than 20 mm thick cement plaster of 1: 3 mix shall be-laid on the completed portion of the bed. To ensure proper thickness of mortar being laid and to achieve perfect level in spreading of cement mortar L-shaped wooden frames of 1x 1.5 m made of 20 mm thick wooden planking, shall be used. The plaster shall be well pressed while laying so that any excess of water or air locked into pores is driven out, thereby exercising uniform plaster over the layer of tiles. The surface of the plaster shall be finished even and smoothened after lightly sprinkling it with pure cement. This ensures a smooth hard surface thus checking the erosion of the surface of the plaster by water action.

For Double Tile Lining

When double tile lining is to be laid either on bed or on side slopes, not less than 15 mm thick sandwiched layer of 1:3 cement sand mortar shall be laid by using L-shaped wooden frames of 1x 1.5 m made of 15 mm

thick wooden planking. This shall be done to ensure that correct thickness of 15 mm is obtained over the whole surface. The plaster shall be well pressed while laying so that any-excess of water or air locked into pores is driven out, thereby providing uniform plaster over the first layer of tiles. The upper side of the plaster shall be made rough for proper bond with the upper layer of tiles by means of fiber brushes or brooms. Wire brushes and nails shall not be used for the purpose.

The cement sand plaster shall be kept well wetted on the sixth day.

- Laying Top Layer of Tiles - Seventh Day

The top layer of tiles in case of double tiles lining shall be laid in 1: 3 cement mortar about 16 mm thick. This layer of tiles shall be laid firmly and properly to proper levels in beds and correct slopes on the sides with joints not more than 10mm thick.

Tiles used on the top layer shall be the best and laid with greater precision. Vertical joints shall be laid flush with cement mortar and no cement pointing shall be done on top of the tiles. The completed lining shall be checked for level with wooden templates and spirit levels.

(8) Inspection and Curing

Daily inspection of the work shall be carried out at the site and the joints found empty shall be localized and thereafter filled properly and re-laid, if necessary.

Work done on each day shall be kept thoroughly wet for curing. In case of single tile lining, subsequent to laying of cement plaster layer and after 24 to 36 hours; and in case of double tile lining after laying the second layer of tiles, the lining shall be cured for at least 28 days. For bed, this may be done by constructing 1SO mm deep earthen bonds across the bed so that a small depth of water-shall stands on the upstream of the bunds and curing assured. The curing of side slopes may be done by constructing masonry drains with weep holes or perforated pipes on the coping at the top of the lining or by using sprinklers.

(9) Maintenance during Laying

During the progressive construction of lining the labour shall walk on footpaths of planks provided for the purpose. Walking on layer of tiles, finished plastered surface or the lined portion of the canal unless properly set and cured for a period of 15 days, shall not be permitted. Such irregularities may cause dislodgement of tiles resulting in previous lining.

Safety ladders shall be constructed in canal lining where shown on the drawing or as directed by the engineer.

(10) Test and Standard

The test and standard shall conform to IS 3872:2002 and IS 3367:1993.

(11) Measurement and Payment

The measurement of the brunt clay tile lining works of required thickness shall be in Sq.m.

Payment for the brunt clay tile lining works shall be made as per contract unit rate as specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1907 SLATE LINING

(1) Scope

This Clause covers the canal lining by slate of specified size and thickness and pointing in cement sand mortar of specified ratio. This type of lining may be feasible in Hilly/Mountainous region where slates of different thickness are easily available. Slate deposits are available in some parts of Tanahun, Udayapur, Kavre, Sindhupalchowk, Dolkha, Syangja, Nuwakot, Dhading, Kalikot, etc districts of Nepal where such lining maybe

technically and economically feasible.

(2) Materials

Cement, Sand and Water: Refer Section 1906(2).

Slate: Slate to be used for canal lining should be smooth, and square in size and thickness required. The slates shall be of uniform size, color and texture, free from white patches and be hard and brittle but not tough. It should be strong to resist wear and tear and should be water repellent as well as resistive to most chemicals.

(3) Construction

Slate lining shall be started after the completion of canal profile, cross section and level required. Slate of required size and thickness shall be laid over the prepared base starting from one end of the canal, ensuring that tiles are properly aligned with minimal gap between them. Joints shall be pointed with 1:3 cement sand mortar. Finished surface of the slate lining should be smooth, without any humps at the joints.

(4) Measurement and Payment

The measurement of the slate lining works of required thickness shall be in Sq.m. Payment for the slate lining works shall be made as per contract unit rate as specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1908 BRICK BLOCK LINING

(1) Scope

This Clause covers the canal lining by brick block of specified size and thickness constructed in 1:4 cement sand mortar and filling gaps with graded gravel filter. This type of lining may be feasible in Canal in cutting and escape and drainage channels.

(2) Materials

Cement, Sand and Water: Refer Section 1906(2).

Brick: Refer Section 600.

Graded Gravel: Refer Section 1917(2).

(3) Construction

Brick Block lining shall be started after the completion of canal profile, cross section and level required. Brick blocks of required size and thickness shall be laid staggered manner over the prepared base starting from one end of the canal, ensuring that blocks are properly aligned with 2cm gap between them. Brick blocks shall be 50cm x 50cm in size with 20 cm thickness constructed in 1:4 Cement sand mortar. Brick block works should be properly cured before placing the graded gravel filter in joints. Joints shall be filled with graded gravel filter. Finished surface of the brick block lining should be smooth, without any humps at the joints.

(4) Measurement and Payment

The measurement of the brick block lining works of required thickness shall be in Sq.m. Payment for the brick block lining works shall be made as per contract unit rate as specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1909 PRECAST CONCRETE BLOCKS LINING

(1) Scope

This Clause covers canal lining with precast concrete (1:2:4) block of specified size and thickness.

(2) Materials

Cement, Sand and Water: Refer Section 1906(2).

Precast Concrete block: Refer Section 800.

(3) Construction

Precast Concrete Block (1:2:4) lining shall be started after the completion of canal profile, cross section and level required. Precast Concrete block of regular hexagonal size (side of regular hexagonal block = 20 cm) and thickness (10 cm) shall be laid over the prepared base starting from one end of the canal, ensuring that blocks are properly aligned with minimal gap between them. Joints shall be pointed with 1:3 cement sand mortar. Finished surface of the Precast Concrete Block lining should be smooth, without any humps at the joints.

(4) Measurement and Payment

Measurement for payment for precast concrete blocks for canal lining shall be made in square meter of concrete blocks placed. Payment for the precast concrete blocks lining works shall be made as per contract unit rate as specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1910 SOIL CEMENT CANAL LINING

(1) Scope

This Clause covers the general guidelines for lining irrigation canals with 100 to 150 mm thick soil cement lining. The use of soil-cement lining for irrigation canals shall be restricted to small and medium-size irrigation canals with capacities up to 10 cumecs and in which the velocity of water does not exceed 1 m/s.

(2) Materials

The cement shall conform to the requirements of IS 269 or IS455 or IS 1489(Part l) or IS 1489(Part 2), IS 8112 or IS 12269.

Sandy soil or soil 100 percent passing 1.0 mm IS Sieve containing not more than 20 percent material passing a 75-micron IS Sieve shall be used for soil-cement lining. It should not contain injurious salts like sulphate and should not have more than one percent (by weight) of organic matter. The liquid limit of the soil shall not normally be above 40 and the plasticity index not more than 18.

Water to be used for soil-cement lining and its subsequent curing shall confirm the requirements specified in IS 456.

(3) Laboratory Tests for Soil and Soil Cement

Detailed soil survey shall be carried out, and the following information shall be obtained for the entire length of the canal before the commencement of the work.

(a) Characteristics of soils and extent of various types of soils encountered on the project and the likely presents and nature of injurious salts in them.

(b) The position of sub-soil water level and range of variations, and

(c) The capacity of the irrigation canal and the velocity of flow.

Sieve analysis of the soil shall be conducted to verify the acceptability of the soil. Laboratory tests shall also be carried out to determine the optimum moisture content and maximum dry density in accordance with IS 4332 (Part 3).

The cement content of the soil-cement mixture shall be such that the mix, after being compacted at optimum

moisture content, satisfies the following requirements:

(d) It shall have a minimum compressive strength of 20 kg/cm2 at the age of 7 days, the test specimens being moist cured during the period;

(e) Test specimens shall effectively withstand erosion by the continuous lateral action of jets of water with a velocity of 1.5 m/s for at least 150 h; and

(f) The permeability of test specimens shall not exceed 10-5 cm/s.

(4) Preparation of Subgrade

The subgrade shall be prepared, dressed, compacted and treated in accordance to clause 7 of IS 7113:2003. The lining shall be started only when at least 35m length of canal with subgrade is properly dressed to receive lining. Where spring level is high the water table shall be lowered to at least 30 cm below the subgrade by dewatering.

(5) Construction

- Pulverizing the Soil

The soil shall be pulverized manually or mechanically to make sure that there are no clods and the soil conforms to clause 1909 (2) above.

- Mixing Soil and Cement

The required quantity of cement shall be thoroughly mixed with the dry soil either mechanically or by hand mixing through manual labour. The mixing shall be continued till the soil-cement mix acquires uniform coloration which can be examined under a magnifying glass. The required quantity of water will be added and mixing continued to ensure uniform distribution of the moisture throughout the soil-cement mass.

Batching of the materials shall be by weight. The appropriate quantities of soil and cement required for one batch shall be measured out after making due allowance for the moisture present in the soil. The correct amount of water to bring the moisture content of the mix to the optimum giving due allowance for evaporation shall be then added.

- Placing

The mixed material shall be discharged uniformly on to the prepared subgrade and distributed to a uniform loose layer by means of shovels and rakes. Care shall be taken to obtain uniformity in depth. Sufficient depth of loose material to give the required thickness after compaction shall be spread in one operation. The thickness of the soil-cement lining should be 100 to 150 cm. Generally, it is necessary to process 130 to 150 mm of loose soil to obtain a compacted thickness of 100 mm.

- Compaction of the Soil-Cement mix

Compaction shall be carried out continuously as the mixed material is spread, but the equipment shall be kept sufficiently far back from the free edges of the layer to prevent lateral movement of the mixed material. The compaction shall be affected by means of a smooth wheeled roller, vibratory roller, tampers or any other type of equipment capable of achieving the desired degree of compaction.

The time between preparation of the soil-cement mixture and commencement of the compaction shall be as short as possible, and in no case shall exceed 30 min. Compaction of any portion of the layer to require density shall be completed within 1.5 hour after the material has been spread.

- Curing

After final compaction and finishing, the surface shall be allowed to harden and soon after it shall be kept continuously damp for at least 14 days. This may be done by any suitable method, such as fog-spraying with water or covering the surface with damp hessian, straw or sand maintained moist throughout the period of

curing.

- Jointing

A straight transverse construction joint shall be formed wherever there is a break of work (of even a few hours). Such joints shall be sealed leak tight with sealing compound conforming to the requirements given IS 5256 after the expiry of the curing period. As an alternative, the edge surface of the previous lining may be roughened with 1:3 cement sand grout not more than 12 mm thickness applied and the lining operation continued.

(6) Field Control

(a) **Subgrade Condition**: Prior to placing of the soil-cement the conditions of the subgrade shall be checked to ensure that it is well compacted (to a density not less than 95 percent of the standard maximum for the soil) clean and the surface moist.

(b) **Cement Content**: An adequate cement content is a primary control factor deserving maximum attention in the field. Samples of the mixed materials from a batch shall be frequently examined to ensure that they are uniform in colour and texture.

(c) **Moisture Content**: The moisture content of the soil and soil-cement mixture shall be checked at regular intervals prior to batching and whenever the source of soil is changed from one stock-pile to another and after mixing.

(d) **Compaction of the Soil-Cement Mix**: The dry density of the compacted soil-cement mix shall be measured at intervals of 1000 m along the length of the canal at points widely distributed across its bed and slopes. In no case shall be measured dry density fall below 95 percent of the maximum dry density obtained in accordance with IS 4332 (Part 3).

(e) **Thickness of Processed Layer:** This shall be checked continuously during the construction to ensure that the correct thickness is being laid.

(f) **Surface Finish:** There shall not be any undulation in the level of the final surface either transversely or longitudinal y of more than 5 mm under one metre template of straight-edge.

(g) **Curing:** It shall be ensured that surface of the soil-cement is maintained moist continuously throughout the curing period by checking at frequent intervals.

(h) **Compressive Strength:** When it is desired and when time permits the compressive strength test may be used as an additional field control measure. The compressive strength of soil-cement specimens moulded from field samples should not be less than, 15 kg/cm^2 at the age of 7 days, the specimens being moist cured during this period.

(7) Measurement and Payment

The measurement of the soil cement lining works of required thickness shall be in Sq.m.

Payment for the soil cement lining works shall be made as per contract unit rate as specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1911 SHOTCRETE CONCRETE LINING

(1) Material

The shotcrete is a mixture of cement, sand and water. It shall comprise of 100 parts by weight of cement, 300 parts by weight of quartz sand, 35-50 parts by weight of water and 2 parts by weight of approved quick setting compound. In general, dry mix shotcrete shall be used.

Ordinary Portland cement conforming to IS: 269 shall be used in shotcreting.

Sand for shotcreting shall comply with the requirements stipulated in IS: 383. In general, sand shall neither be too coarse to increase the rebound nor too fine to increase the slump. Sand shall have a moisture content between 3 to 6 per cent.

The grading of sand shall lie within the limits given in Table 19.5.

Table 27.1: Grading of Sand

Sieve Designation	Percent Passing the Sieve
4.75 mm	95 – 100
2.36 mm	65-90
1.18 mm	45-75
0.600 mm	30-50
0.300 mm	10-22
0.150 mm	2-8

For thick sections it may be advantageous to incorporate coarse aggregate in the mix provided adequate shotcreting equipment is available. Coarse aggregate, when used, shall conform to grading given in Table I of IS: 9012. The percentage of coarse aggregate shall be kept as 20 to 40 percent of the total aggregate and the mix shall be suitably designed.

Water/cement ratio for shotcreting shall fall within the range 0.35 to 0.50 by mass, wet enough to reduce the rebound. Drying shrinkage may be between 0.06 percent and 0.10 percent. The quick setting compound shall be added at the nozzle with water just before shotcreting.

Admixtures shall meet the requirements of IS: .456-1978 and IS: 9103-1979.

Reinforcing bars if used shall conform to IS: 432 (Part I)-1966 or IS: 1139-1966 or IS: 1786-1966. Welded wire fabric conforming to IS: 1566-1967 also may be used.

(2) Workmanship

A good base or foundation shall be prepared for application of shotcrete. Where the shotcrete is to be placed against earth surfaces as in canal linings, such surfaces shall first be thoroughly compacted and trimmed to line and grade. Shotcrete shall not be placed on any surface which is frozen, spongy, or where there is free water. The surface shall be cleaned of all loose and foreign materials and shall be kept damp for several hours before applying shotcrete.

The forms shall be plywood sheeting or other suitable material, true to line and dimension. They shall be adequately braced to protect against excessive vibration, and shall be constructed so as to permit the escape of air and rebound during the gunning operation; this is of particular importance in the case of thick structural members. Short removable bulkheads may be used at intersections. Forms shall be oiled or dampened, and they shall be cleaned just before gunning. Adequate and safe scaffolding shall be provided so that the operator can hold the nozzle at the optimum angle and distance from the surface for all parts of the work. The scaffolding shall be also given easy access to the shotcrete surface for screeding and finishing, if such is specified. Scaffolding shall be constructed to permit uninterrupted applications of the shotcrete wherever possible.

The cement and sand shall be batched and mixed and conveyed through a hosepipe with the help of compressed air. A separate line shall bring the water under pressure. The cement, sand water mix shall be passed through and intimately mixed in a special manifold and then projected at high velocity to the surface being repaired. The density of shotcrete shall not be less than 2000 kg/cu.m. The strength of shotcrete shall not be less than 25 N/mm^2. For effective shotcreting, the nozzle shall be kept 60 to 150 cm away from the surface, preferably normal to that surface. While enclosing reinforcement bars during repairs, the nozzle shall be held closer at a slight angle and the mix shall be wetter than the normal.

Test panels simulating actual field conditions shall be fabricated for conducting pre- construction testing. The procedure for testing the cubes or cylinders taken from the panels stipulated in Clause 6 of IS: 9012 shall be followed.

It shall be ensured from tests that strength of about 25 N/mm2 at 28 days is available for the mortar/concrete mix.

The defective concrete shall be cut out to the full depth till sound concrete surface is reached. Under no circumstances the thickness of concrete to be removed shall be less than clear cover to the main reinforcement. No square shoulders shall be left at the perimeter of the cut-off portion and all edges shall be tapered. Thereafter, all loose and foreign materials shall be removed and the surface be sand-blasted to make it rough to receive shotcrete after applying a coat of bonding epoxy as per recommendation of the manufacturer at the rate of 1.0 kg per 1.5 sq.m of surface area.

The exposed reinforcement shall be thoroughly cleaned free of rust, scales etc. by wire brushing. Wherever the reinforcements have been corroded, the same shall be replaced or supplemented by additional reinforcement. Before application of shotcrete, a coat of neat cement slurry shall be applied on the surface of the reinforcement.

Sufficient clearance shall be provided around the reinforcement to permit encasement with sound shotcrete. Care shall be taken to avoid sand pockets behind the reinforcement.

A thickness of 25 to 40 mm of shotcrete can normally be deposited in one operation. If, for some reason, the total thickness is to be built up in successive operations, the previous layer shall be allowed to set but not become hard before the application of the subsequent layer. It shall always be necessary to apply shotcreting on a damp concrete surface.

Where required, welded wire fabrics 5cm x 5 cm x No.10 gauge shall be provided in the first layer of shotcreting. The fabric shall be tied properly. In case the damage to the concrete member is too deep, the Specifications for shotcreting as well as requirement of placement of wire mesh has to be decided as per field conditions.

The stipulations given in IS: 9012 regarding application of shotcrete shall be followed so as to keep the rebound to the minimum. The quality of shotcreting and workmanship shall be such that the percentage of rebound mentioned in IS 9012 is adhered to. In no circumstances shall be rebound material be re-used in the work.

It would be desirable that green shotcrete is moistened for at least 7 days. Shotcreting work shall not with be done during windy rainy conditions.

(3) Quality Control

The mix proportions, grading and quality of aggregate, amount and spacing of reinforcing steel, position of the work, design and condition of delivery equipment, and the quality of workmanship all affect the quality of shotcrete in place. A laboratory investigation shall, therefore, be carried out prior to the commencement and completion of the work as per Clause 6 and 8.12 of IS 9012: 1978.

(4) Measurement and Payment

Shotcreting shall be measured in square meter of surface area of application. The quantities measured as

above shall be paid at their respective full and the final compensation to the contract unit rates which shall be the Contractor as per Clause 115.

Mobilization and demobilization and shifting of equipment, construction of form work / staging shall be measured separately on lump sum basis and paid.

1912 FABRIC FORM CONCRETE MATTRESS LINING WITH FILTRATION POINTS

Refer to Clause 1519 and 1520 of Section 1500 of this specification.

1913 CONCRETE CANVAS LINING

(1) Scope

This Clause covers the general guidelines for installation of Concrete Canvas Lining for in a manner that maximizes safety, efficiency, and the physical integrity of the material and channel.

(2) Material

Concrete canvas (CC), is a flexible, concrete filled geosynthetic, that hardens when hydrated to form a thin, durable, water proof, eco-friendly and fire resistant concrete layer. Concrete canvas concrete does not require plant or mixing equipment as it is positioned on surface and added with water.

Concrete canvas consists of fiber reinforcement imbedded within its structure. An LLDPE geomembrane backing ensures the material has very high impermeability. The material can be hydrated either by spraying or by being fully immersed in water. Once set, the fibers reinforce the concrete, preventing crack propagation and providing safe plastic failure mode.

Table 19.4 Physical Properties of Concrete Canvas

Pre Set Properties	
CCX™ Type	CCCX-B™
Thickness (mm)	11
Roll Width (m)	1.9
Mass Per Unit Area (Kg/m^2)	14.5-15.5
Bulk Roll Coverage (m^2)	95
Bulk Roll Length (m)	50
Density(Kg/m^3)	1500-1600
Density Increase on Curing (% Increase)	20-25
Peel Strength - strength of internal linking fibers (KN/m)	>4.0
Post Set Properties	
Compressive Strength of Cementitious Mix	>70
Flexural Strength	
-Initial Breaking Load	>2500
-Initial Flexural Strength	>4
-Final Flexural Strength	>10
Abrasion Resistance (mm/1000 Cycles)	<0.2
Manning's Roughness Coefficient (n)	0.010-0.015
Water Permeability (m/s)	$6*10^{-12}$

(3) Installation

Concrete Canvas shall not require specialist contractors for the majority of applications. Installation is quick and easy, provided that installation guidelines are followed and the appropriate equipment is used.

Deployment

The site shall be cleared of debris, vegetation, and loose materials. The surface shall be relatively smooth and free from sharp objects that could potentially puncture the Concrete Canvas. CCX-B or equivalent shall be unrolled to line earth canals making sure it is positioned correctly to achieve the desired coverage. Personnel shall not wear damaging shoes and shall avoid walking on the CC surface to prevent staining, particularly with wet footwear prior to hydration. On restricted access projects where installers have no option but to walk on CC, the surface can be protected by using timber boards to prevent boots from creating depressions in the material. When positioning subsequent layers, ensure there is at least a 100mm overlap in the direction of water flow (shingled like roof tiles) and that the material layers are in intimate contact with each other.

Appropriate anchoring methods shall be used to secure the Concrete Canvas to the ground. Common methods include digging trenches along the edges and burying the material or using stakes to secure it in place.

Jointing

Top layer shall be folded back and the material shall be hydrated under the overlapped sections of the CC. This is important to ensure the joint cures to optimum strength. Once hydrated, the material remains workable for 1 to 2 hours. CC approved sealant shall be applied, an 8mm diameter continuous bead shall be placed along the line where the screws will be positioned (eg. for a 100mm overlap with screws 30mm from the edge of the top layer, the sealant bead needs to be 70mm from the edge of the bottom layer)

The top layer shall be folded back into position and stainless screws shall be inserted at the specified centers (e.g. 100mm, 200mm, 100mm Zigzag), at the specified distance from the edge of the CC (e.g. 30mm, 50mm, 15mm & 50mm).

It shall be ensured that there is no rucking at the joint and both layers are in contact with each other. Care shall be taken during installation to avoid damage occurring to the CC. If any CC is damaged during installation and before hydration, the layer shall be removed and replaced.

Perimeter Edge Fixing

All exposed (i.e. unjointed) edges of the CC shall be secured during the installation to prevent water ingress underneath the CC which might cause wash-out of the substrate and subsequent undermining.

When fixing to Soil (i.e. using anchor trenches):

• CC shall be positioned over the shoulder of the channel and into the anchor trench.

• The CC shall be fixed in the anchor trench by inserting fixing pegs through each overlap or at a minimum of 2m intervals for longitudinal installations.

• The CC shall be hydrated before backfilling with non-erodible fill. This might be soil or concrete depending on the design. The construction drawings shall be constructed.

When fixing to Concrete/Masonry/Rock:

• The construction drawings shall be consulted for the mechanical fixing specifications and fixing spacing.

• The CC shall be positioned against the structure and drill a pilot hole through the CC and the structure before inserting the mechanical fixing.

• Appropriate sealant/gasket and washers/clamping shall be fixed bar as specified by the designer to ensure a strong, watertight seal.

It shall be ensured that the leading edge of the final layer of CC is either suitably terminated into existing infrastructure and fixed to prevent water ingress (e.g. using stainless steel clamping bar and gasket), or tucked into an anchor trench which shall be backfilled to prevent scour beneath CC.

Intermediate Fixings

Additional intermediate fixings shall be necessary to profile CC on uneven substrates to ensure it conforms to the underlying surface and remove voids, or to resist the following load conditions:

• Hydraulic Shear Loads: e.g. lining channels with an incline >10%

• Wind Loads: e.g. in exposed locations where slope lengths exceed 7m

• Warmer Climate Detailing: e.g. where CC profile lengths exceed 3m

The intermediate fixing type, performance requirements and installation locations shall be specified by the designer to suit the anticipated load conditions. 'Round Head' fixing pegs are typically used for profiling and warmer climate detailing. When a greater head plate diameter or pull-out strength is required, for example when designing to resist hydraulic shear or wind uplift, larger intermediate fixings such as Earth Percussion Anchors may be specified. Mid-channel anchor trenches (known as check slots) may also be required by the designer, or incorporated into large installations at the end of the working day to prevent scour and undermining of the CC before returning to continue the installation. The construction drawings shall be consulted.

Hydration

If necessary, the Installer shall place temporary ballast, such as sandbags, on top of the laid CC prior to hydration to prevent wind uplift and ensure that it lies flat to the substrate on undulating ground to prevent voids from forming underneath the material.

After fixing and jointing, the surface of the CC shall be brushed clean to remove marks and debris before spraying with water to hydrate. The fiber surface shall be sprayed multiple times until the CC is fully saturated. The wet CC will first darken and then become lighter as it absorbs the water.

High pressure water shall not be sprayed directly onto the CC as this may wash a channel in the material. CC shall be hydrated using fresh water or salt water, it is not possible to over hydrate CC and it will hydrate and set underwater. A minimum volume of water equal to 40% of the material weight is required.

To check proper hydration, the CC shall be felt wet to the touch several minutes after hydration. Thumb shall be pressed into the CC and released. If water is present in the depression in the CC, it has been sufficiently hydrated. If no water is observed, then more water must be applied.

Specific hydration methods shall be required in drying conditions (installing in high air temperatures (>22°C), wind (>12km/h), strong direct sunlight or low humidity (<70%)) and in low temperature conditions. The CC User Guide shall be consulted, if required.

It is not recommended to rely on rainfall to provide hydration.

Setting

There shall be a working time of 1-2 hours after hydration. Anchor trenches shall be backfilled with non-erodible fill as specified in the construction drawings to create a neat termination and encourage surface water runoff to flow over the anchor trench and in to the CC channel.

CC hardens to strength in 24 hours and is then ready for use. Allow the CC to cure for at least 48 hours before applying any post installation surface treatments such as jet washing or painting.

If installation continues the following working day, the edge of the last layer of CC shall be protected overnight with waterproof sheeting to enable jointing on return to work. Alternatively, check slots shall be installed.

(4) Inspection, Maintenance and Repair

CC lined structures shall be inspected 24hours after hydration and at regular intervals thereafter. The CC User Guide: Inspection, Cleaning and Maintenance shall be consulted for more details. For the majority of projects, CC shall not require cleaning or maintenance. If damage is found during a periodic inspection, Concrete Canvas Ltd shall be contacted for repair advice.

(5) Equipments

Equipment required like Auto fed screw driver, Water Pump, Snap off knife, Adhesive applicator gun, etc shall be as per the specification and the requirements.

(6) Measurement and Payment

The measurement of the Concrete Canvas lining works of required thickness shall be in Sq.m.

Payment for the Concrete Canvas lining works shall be made as per contract unit rate as specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1914 LAYING PVC SHEET

PVC geo-membrane (flexible polyvinyl chloride) lining of different thickness are used in canal, pond and reservoir lining to control seepage. The PVC geo-membrane shall comply with IS 15909:2010.

The PVC geo-membrane shall be suitably manufactured from vinyl chloride resin homo polymer. Water soluble compounding ingredient shall not be used. Plasticizers that are resistant to migration and bacterial growth shall be used. The PVC geo-membrane shall be pigmented to produce a uniform colour. The material shall conform to the test and requirements as given in Table 1 of IS 15909:2010.

The PVC geo-membrane shall be uniform in colour, texture and finish. The colour, unless specified, shall be black. It shall be free from pin-holes and other foreign particles when tested by the method prescribed in Annex A of IS 15909:2010. The laminated film shall not peel off.

The PVC geo-membrane shall be reasonably free from defects such as holes, tears or blisters. The edges shall be free of nicks and cuts visible to the naked eye. If two or more pieces of geo-membranes are used, the material shall be joined together by a suitable heat sealing process keeping an overlap of at least 2.5 cm.

PVC Geomembrane laying work shall be measured in Sq.m and shall be paid as per the contract unit rate, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1915 LAYING PLASTIC SHEET

This section covers aspects of lining of canals with polyethylene film. The low density polyethylene film shall conform to IS 2508:1984 and should be of nominal thickness not less than 150 microns (thickness to be designed based on type of subgrade and water depth) and should be black in colour. High density polyethylene film shall conform to IS 10889:1984.

For necessary information to be collected before commencing work reference should be made to IS 10430:1982. The subgrade should be prepared according to IS 3873: 1993 to the required cross-section to accommodate the top cover. KANKAR or any sharp angular material shall be removed to provide reasonably smooth subgrade. Any weeds, roots and vegetation, that may damage the film, shall be removed.

For smaller canals, where the width of film available is sufficient to cover the canal section from one end to the other, no toe wall is necessary and the polyethylene film lining should be laid continuously from one end to the other. For larger canals, a masonry toe wall of appropriate size should be constructed at two extremities of the bed. With a view to providing an anchor for film laid-both on bed and sides.

A trench 150 x 150 mm for canals having capacity up to 10 cumecs and minimum 250 x 250 mm for canals having capacity greater than 10 cumecs, depending upon the size of the canal, at a distance of 400 mm away from the lip and 300 mm above the FSL shall be dug all along the canal length, to hold the loose end of film laid on side slopes.

If the reaches are weed and termite infected, suitable anti-weed treatment and anti-termite treatment of the subgrade may be done to discourage weed growth under the film.

A layer of fine sand of thickness 12mm to 25 mm should be provided over the subgrade (on bed only) to facilitate working conditions over the film. The film should be laid over the prepared subgrade, below the designed level to the extent of cover thickness, in strips preferably perpendicular to water flow depending upon the width of the film, width of the bed and perimeter of the section. Longitudinal joints should be avoided. Loose ends of the film sheet should be anchored with an allowance of 500 mm for anchoring in the toe wall.

A trench as given above should be excavated and the film anchored as shown in Fig. 2 and filled up with the excavated material where earth cover is provided. Stone or concrete coping may be provided to cover the trench to avoid rainwater from filling the trench.

Toe walls should be constructed at such a level that film when laid on the bed is retained at design depth. Adequate space should be available at the toe wall for anchoring the film.

The film should be spread loosely over the subgrade so that it attains the contours of the subgrade and compensates for thermal variation during the day. It is recommended that an extra length of 3.5 percent, over the length of film required for spreading over the bed and the side slopes including anchorage, should be provided to take care of thermal variations during the day.

As polyethylene film is likely to be affected by very high temperatures of about 45OC obtained in summer days, it would be advisable to avoid laying of the film under such high temperatures. In case it is necessary to continue the work on hot days as well, working should be restricted to morning hours only.

Adjacent layers of film should be laid in such a manner that the width of an overlap should not be less than 150 mm and the overlap should point downstream. The joint shall be done by one of the following method : Simple Overlapping, Folded Overlapping, Joining by Hot Bitumen, Sealing by Adhesive Tapes or Heat sealing as per IS 9698.

The top cover of an earth layer of suitable thickness, precast concrete tiles In-situ cement concrete, stone slab or bricks shall be provided. Minimum thickness of cover over the film sheet should not be less than 300 mm in bed and 600 mm on the sides. If the cover material contains KANKAR or sharp angular material, a cushion layer 75 mm thick, of sieved earth (free from KANKAR, etc) may be provided over the film. To prevent ‘beaching effect’ at the water line, KANKAR or gravel of stone aggregates of size 40 to 50 mm may be spread over the cover prior to compacting, using light rollers or manual ramming.

In case of rigid cover, it should be so placed that the aggregates do not puncture the film. For a better bond between the smooth surfaces of film land rigid cover, a 15 mm sand cushion of fine sand may be provided over the film sheet or cement slurry may be sprayed over the film before placing in-situ cement concrete as rigid cover.

The film should be sandwiched between two layers of hard surface lining in rodent infested areas so that rodents may not attack and damage the film from outside the channel.

1916 GEOMEMBRANE AND DRAINAGE COMPOSITE

Geomembrane are relatively impermeable sheets of plastic, used as an impermeable layer to check the liquid movement in canal lining. Geomembrane shall comply with requirement of Clause1507 of Section 1500 in this Specification.

Drainage Composite (also known as Geo-composite) is a composite material made from different

Geosynthetics products to serve their functions simultaneously. Geocomposite which is being used in canal lining is comprises of impermeable membrane, drainage net and filter Geotextile which together form a drainage layer with added waterproofing function.

Drainage Composite shall comply with requirement of Clause 1508 of Section 1500 in this Specification.

1917 DRAINAGE ARRANGEMENT FOR PORE WATER PRESSURE RELEASAE

(1) Pressure release safety valve

Unplasticised Polyvinyl Chloride (uPVC) made pressure release valves shall be fitted at the suitable intervals as shown on the drawings or as directed by in the concrete lined section of the main canal and the RCC structures as requirement of subsurface drainage arrangement. The valves shall be and dia. fitting with T-Joints of respective sizes. The joints shall of soils into the fitted uPVC pipe.

The specimen samples of pressure valves shall be supplied well in advance for its test and subsequent approvals. Such specimens shall be from standard and reputable manufactures in the international markets or as required recommended by the engineer. The specimen shall be supplied with test certificates supplied by their manufacturers and specifications.

The pressure release valves shall be tested for its different head and comply with clause 8 of IS 4558:1995.

(2) Gravel Filter

Unless otherwise directed by the Engineer, gravel filter shall be placed and compacted under the lining and boulder pitching. The filter shall be as specified in the Drawings or as directed by the Engineer.

The granular material used for the graded filter shall be obtained from the sources approved by the Engineer, and be hard, dense and free from clay and other foreign matters. It shall be well graded in accordance with the following limits:

- Maximum size shall be 40 mm.
- Grading coefficient (60% size/10% size) shall be greater than 4.
- The 15% size shall be less than 5 times the 85% size of the soil to be protected.
- The 15% size shall be less than 20 times the 15% size of the soil to be protected.
- The 50% size shall be less than 25 times the 50% size of the soil to be protected.
- The 15% size shall be greater than 5 times the 15% size of the soil to be protected.

The grading of the soil to be protected shall be determined by the Contractor at locations directed by the Engineer.

The filter shall be placed in two equal layers. The lower layer shall contain finer material and the upper layer the coarser material. The filter shall be designed and compacted as approved or directed by the Engineer.

Measurement for payment of gravel filter shall be made in cubic metres as placed according to the Drawings, or as instructed by the Engineer. Payment for the graded gravel filters shall be made at the contract unit rate as per the Bill of Quantities. The unit rate shall include all costs of extracting, loading onto trucks, hauling, unloading, storing, testing, placing, mixing of different grades, spreading and compacting of the graded filter gravel.

(3) UPVC perforated pipe

Unplasticised Polyvinyl Chloride (UPVC) pipes of 100 & 140 mm outer diameter shall be provided as pressure relief pipes in downstream floor and piers in under sluice and barrage main bays portion. The uPVC pipes shall be manufactured as per NS 206/046 or relevant IS Standard. The pipes should withstand a pressure of 4 kg/cm2. The vertical and horizontal perforated UPVC pipes shall be laid as shown on the Drawings, or as

directed by the Engineer. The horizontal pipes shall be perforated uPVC pipes and the perforation area shall be as specified in the Drawings, or as directed by the Engineer.

The horizontal UPVC pipes shall be laid on as shown in the Drawings. The specification of the gravel filter as required and shown in the Drawings shall be as specified in the Clause 6.5. Measurement for payment of gravel filter shall be made at the unit rate per cubic metre for Item No. B-1 of the Bill of Quantities.

The horizontal and vertical UPVC pipes shall be connected by the UPVC T junction and uPVC pipe 900 bends, of 100 mm and 140 mm internal dia fitting the pipes to inserted as specified in the Drawings, or as directed by the Engineer. Joints shall be made in such a way that they do not permit entry of soil into the pipe.

Measurement for payment of uPVC pipe for pressure relief shall be made in place to the length of uPVC pipe installed as shown on the Drawings or as directed by the Engineer. Payment for vertical, horizontal and connecting uPVC pipes for 100mm dia. and 140 mm dia. pressure relief shall be made at the unit rate per linear metre for Item No. F-1 and F-2 of the Bill of Quantities respectively. The unit rate shall include all costs of furnishing, transporting, cutting perforations and placing of uPVC pipes, including cost of all labour, materials and equipment. Payment for uPVC T junction and uPVC pipe 900 bends for 100mm dia. and 150mm dia. for pressure relief arrangement shall be made at the unit rate per number for Item No. F-3 and F-4 of the Bill of Quantities respectively. The unit rate shall include all costs of furnishing, transporting, joining and placing, including cost of all labour, materials and equipment.

1918 LAYING FILTER OF GRADED STONE AGGREGATE

Refer Section 1917 (2).

1919 LAYING SAND FILTER

(1) Scope

This Clause covers the canal lining by sand filter of specified thickness and dressing, leveling and compaction after water sprinkling. This type of lining has now become out of practice. However, such lining used for small canals in remote hilly areas where sand is locally available but transportation of material for other type of lining is difficult. Sand filters help remove particulate matter and pollutants from water flowing through the canal, improving overall water quality. They can reduce sedimentation in canals, which can otherwise lead to reduced capacity and increased maintenance needs.

(2) Materials

Sand and Water: Refer Section 1906(2). Fineness modulus of sand should be more than 1.25.

(3) Construction

Sand Filter lining shall be started after the completion of canal profile, cross section and level required. Sand of required fineness modulus shall be sprayed in 75mm thickness over canal beds and slopes and thoroughly dressed, levelled and compacted after sprinkling water. Finished surface of the canal lining should be smooth, without any humps elsewhere.

(4) Measurement and Payment

The measurement of the sand filter laying works of required thickness shall be in cubic meter. Payment for the sand filter laying works shall be made as per contract unit rate as specified in the contract, which shall be full and final compensation for the cost of compliances of all requirements specified in Clause 115.

1920 WELL GRADED FILTER UNDERNEATH LINING FOR DRAIN

Refer Section 1917 (2).

1921 JOINTS SEALING WORKS

(1) Sealing compound

This section specifies requirements for sealing compound for joints in concrete lining canals. The sealing process should be taken up after concrete curing period is over. The joints should be thoroughly cleaned of dust and grit before the sides are printed by a portable air blow or brush. Before applying the sealing compound the sides should be sprayed or brushed with a primer conforming to IS 3384: 1985. The primer should be allowed 4 to 12 hours to dry out thoroughly before sealing compound is poured into the joints. One liter of primer should be used for a length not more than 80 running metre of joints of depth of 25 mm.

The physical requirements of the sealing compound shall conform to those given in Table below:

Table 1: Physical Requirements of Sealing Compound

SN	Characteristic	Requirement	Method of Test
1	Softening point, Min	85°C	IS 1205 : 1978
2	Penetration at 25°C, 100 g, 5 s , 1/10	15 (Min) 30 (Max)	IS 1203 : 1978
3	Flash point, Min	200°C	IS 1209 : 1978
4	Pour point, Max	170°C	IS 1834 : 1984
5	Increase in softening point after heating to 20°C above the maximum pour point for three hours, Max	5°C	IS 1205 : 1978
6	Extensibility at 0°C, Min	6 mm	Appendix C of IS 1834 : 1984
7	Water content, percent by weight, Max	0.5	IS 1211 : 1978

The sealing compound should be heated (working temperature 175° to 185°C) in a suitable heater-boiler vessels. The sealing compound is cut in pieces smaller than 15 cm cube by a wetted axe prior to heating. Molten sealing compound poured into the joints with minimum loss of temperature after transferring to a molten pourer from main heater boiler. In the absence of molten pourer, pouring may be done by suitable cans with extended spouts. For a length of 100 running meter of joint of 12 mm thickness and 75 mm depth not less than 40 kg of sealing compound should be used.

It wll be helpful if suitable size of wooden or metallic pieces are laid on each side of the joint in the sealing compound. The sealing compound should be poured till the horizontal joints are filled up to the lower edge. The wooden board or metallic pieces are removed after sealing compound starts hardening.

Precautions must be taken as Primer is inflammable and should not be placed near a naked flame and temperature in boiler should be carefully controlled.

(2) Bituminous Material Filler

The bitumen used shall conform to S 35 of IS: 73-1961 or 85/25 specified in IS: 702-1961.

(3) Compressible Fiber Board Filler

Refer to Clause 2506 of Section 2500.

(4) Backer Rod Filler

Backer Rod is an ideal non-absorbent compressible backup material inserted into a joint to control sealant depth, creating a backstop to allow proper sealant tooling. It can also be used as a temporary joint seal. It is an extruded round, closed cell, low density polyethylene foam material with skin-like outer texture. It is highly flexible and compressible for easy installation. Backer Rod meets a wide range of chemical resistance.

Before installation, joints shall be kept clean, dry and free of obstructions. Proper rod diameters shall be selected and cut to length or used directly from spools. With a blunt instrument or roller, rod shall be uniformly installed at the level recommended by the Engineer.

(5) High Performance joint sealing compound

1922 INTAKE WELL FOR DRAIN

The intake well for drainage shall comply with IS 11570:1985.

1923 VERTICAL NON RETURN VALVE/ VERTICAL NON RETURN POCKET VALVE

The vertical non-return valve/ vertical non-return pocket valve shall comply with IS 5312 (Part 1 and Part 2).

SECTION 2000: IRON GATES AND OTHER WORKS

2001 SCOPE 20-1

2002 IRON GRILL WORKS 20-1

2003 ROLLING SHUTTERS 20-1

2004 MS SHEET DOOR 20-6

2005 COLLAPSIBLE STEEL SHUTTERS 20-7

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2007 GI BARBED WIRE FENCING 20-10

2008 STOP LOG GATES 20-12

2009 SINGLE SCREW SPINDLE GATE (FOR SMALL GATES IN SMALL AND MEDIUM IRRIGATION CANALS) 20-12

2010 SINGLE SCREW SPINDLE GATE (FOR HEAD REGULATOR, CROSS REGULATOR AND ESCAPE IN LARGE CANALS) 20-13

2011 MOTORISED DOUBLE SCREW SPINDLE GATE 20-14

2012 MOTORIZED DOUBLE ROPEDRUM HOIST GATE 20-15

2013 CHAIN LINK FENCING 20-16

2014 CHICKEN MESH FENCING 20-17

2015 SPIRAL RAZOR BLADE FENCING 20-17

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Department of Water Resources and Irrigation
Jawalakhel, Lalitpur

2001 SCOPE

This Clause covers the works for the supply, fabrication and erection of iron gates, shutters, trusses and fencing for buildings and irrigation gates for Canals (Head Regulator, Cross Regulator, Escape, etc.) and other different works related to iron works.

2002 IRON GRILL WORKS

(1) Materials

(a) Steel

Steel sections of specified sizes shall comply with the requirements of IS 2062, IS 1030, IS 2004 or equivalent.

(b) Aluminum Paint

Aluminium paint shall comply with requirements of Section 1403 (6).

(2) Welding and Fixing

The welding shall be fillet-welding confirming to the requirements of IS 816: 1969 or BS-449 or equivalent. The mild steel grill shall be made according to pattern given in the drawings. Welded joints shall be neatly made, filled, smooth and left clean. The site in-charge shall be informed when the welded work is ready for inspection and such work must left unprimed until the site in-charge gives his approval. The contractor shall furnish at his own expense all necessary tools and all materials, which he may require for the safe erection of the work and remove the same when the work is completed. The contractor shall be solely responsible for any damage due to structure during erection.

For fixing grill frame to structure the grips shall be of plastic or metal. The screws shall be steel screws. The grill work shall be cleaned with sandpaper and finished with specified number of coatings of aluminium paints and fixed to the opening.

(3) Tests and Standard of Acceptance

The Steel sections shall be tested as per the requirements of IS 2062, IS 1030 and IS 2004. The welding shall be tested as per the requirements of the IS 816 or BS-449.

(4) Measurement

Fabrication and fixing of iron grill shall be measured in square meters or weight (kg). Welding, painting, and fixing works shall not be measured separately.

(5) Payment

Fabrication and fixing of iron grill shall be paid at the contract unit rates which shall be the full and the final compensation to the Contractor as per Clause 115. Cost for Welding and painting shall deemed to be included in the contract unit rate above.

2003 ROLLING SHUTTERS

This section lays down the requirements regarding material, type, fabrication, assembly and finish of the rolling shutters. The rolling shutters shall comply with the requirements of IS: 6248-1979.

(1) Materials

All finished steel shall be well and cleanly rolled to the dimensions and weight specified by IS subject to the permissible tolerances as per IS: 1852. The finished materials shall be reasonably free from defects. Steel sections shall be free from excessive rust, scaling and pitting and shall be well protected.

Cold-Rolled Steel Strips - Cold-rolled steel strips used for rolling shutter lath sections shall conform to temper No. 5, dead soft quality of IS: 4030.

Mild Steel Sections - Mild steel sheets and plates used for manufacturing the guide channels, brackets and lock plate shall be of hot-rolled steel of thickness not less than 3.15 mm and shall be free from surface defects and edges cleanly sheared (IS : 5986).

Steel Pipes - Mild steel pipes used for the suspension shaft of the roller shall be heavy duty pipe suitable for mechanical purposes and shall conform to IS: 1161.1968.

Cast Iron Castings - Cast iron castings used for roller pulley wheels, U-clamps and bevel gears shall be free from blow holes, surface defects, such as cracks, burns, etc, and shall conform to Grade 15 of IS : 210.

Springs - The springs used in the roller for counterbalancing the rolling shutter shall be made either from high tensile spring steel wire or flat spring steel strip.

- The spring steel wire used for helical spring shall conform to Grade 2 of IS: 4454 (Part I).
- Flat spring steel strip used for spiral spring shall be from 0.8 to 1.0 percent carbon steel strip, especially hardened and tempered.

Malleable Cast Iron - Malleable cast iron used for clips shall conform to IS: 2108.

Aluminium Alloy Sheets - Aluminium alloy sheets to be used for curtain in case of rolling grills, shall conform to 52000 (NS 4), 53000 (NS 5) or 64430 (HS 30) of IS : 737.

Aluminium Alloy Extrusions - Aluminium alloy extrusion for the, components of rolling shutters of aluminium shall conform to 53000 (NE 5) or 64430 (HE 30) of IS: 733.

(2) Fabrication

Curtain - The curtain shall be built up of interlocking lath section formed from cold-rolled steel strips. The thickness off the sheets from which the lath sections have been rolled shall be not less than 0.900 mm for shutters up to 3.5 m width and not less than 1.20 mm for, shutters above 3.5 m width. Curtain above 9 metres in width should be divided into 2 parts with provision of one middle fixed or movable guide channel or supported from the back side to resist wind pressure. The lath section shall be rolled so as to have interlocking curls at both edges and a deep corrugation at the centre with a bridge depth of not less than 12 mm to provide sufficient curtain stiffness for resisting manual pressure and normal wind. Each lath section shall be continuous single piece without any welded joint. When interlocked, the lath sections shall have a distance of 75 mm between rolling centers, although lath sections with 50 mm and 25 mm rolling centers may be used for special purposes, like small show windows, bus windows, etc. Each alternate lath section shall be fitted with malleable cast iron or mild steel clips securely riveted at either end, thus locking the lath section at both ends and preventing lateral movement of the individual lath sections. The clips shall be so designed as to fit the contour of the lath sections.

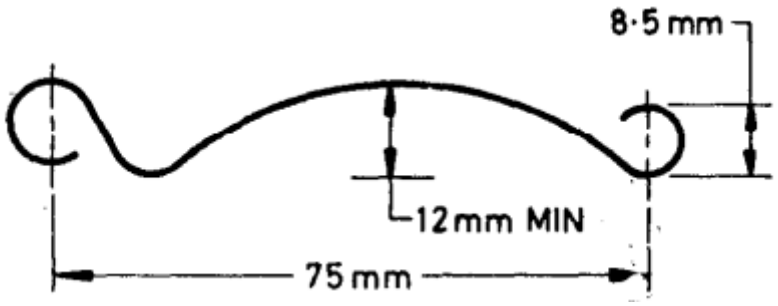

Fig 20.1: Typical Lath Section

Lock Plate - A fabricated lock plate of riveted construction made of mild steel sheet of not less than 3.15 mm thickness, reinforced with mild steel angle section of not less than 35 x 35 x 5 mm size at the bottom, shall be interlocked with bottom most lath section of curtain so as to provide contact against the sill, when closed. Alternatively, the lock plate may also be fabricated out of unequal mild steel angles or 'Tee' section, of not less than 5 mm thickness. The lock plate shall be fitted with sliding bolts at either end to engage with

suitable receiving pockets at the bottom of guide channels. The sliding bolts shall be capable of being locked by means of padlocks both from outside and inside. The lock plate shall also be provided with pulling handles, one handle for widths up to 2.5 m and two handles for widths of above 2.5 m. Pulling handles shall be fixed on both the interior side and exterior side of the lock plate.

Guide Channels- The guide channels shall be of mild steel deep channel section and of rolled, pressed or built up (fabricated) construction. The thickness of the sheet used shall not be less than 3.15 mm. The depth of the guide should be such that there is sufficient clearance between the curtain and the inner surface of the guide to avoid any rubbing or obstruction for free movement of the curtain. The curtain shall project into the guide at least 40 mm up to 3.5 m width and 60 mm for greater width and there shall be a clearance of 10 mm minimum between the guide wall and the end clips of the curtain to permit free movement of the curtain under normal wind pressure. Where the shutter is installed in heavy windy zones special wind locking arrangements shall be provided to prevent the curtain coming out of the guide.

The gap, on either side, between the edge of curtain and the inside edge of the guide channel shall be about 5 mm to allow for the free movement of the curtain and at the same time to prevent rattling of the curtain due to wind.

Size of the guide channel - The depth and width of the guide channel shall be as under:

Table no 20.1 Depth

Clear width of shutter	Depth of guide channel, Min
Up to 3.5 m	65 mm
3.5 m up to 8 m	75 mm
8 m and above	100 mm

Width of guide channel shall be 25 mm for lath sections with bridge depth of about 12 mm and 32 mm for lath sections with bridge depth of about 16 mm.

Each guide channel shall be provided with a minimum of three fixing cleats or supports for attachment to the walls or column-by means of bolts or screws. The spacing of cleats shall not exceed 0.75m. Alternatively, the guide channels may also be provided with suitable dowels, hooks or pins for embedding in the walls.

The guide-channels shall be attached to the jambs, plumb and true, either in the overlapping fashion, projecting fashion or embedded in grooves, depending on the method of fixing.

Bracket Plate - The bracket plate shall be fabricated out of mild steel of 3-15 mm thickness (minimum), thicker plates may be used depending upon the height of shutter. The size of the bracket plate for different heights of different rolling shutters shall be as follows:

Clear Height 'm'	Size of Bracket Plate, Min mm x mm x mm
Up to 2.3	300 x 300 x 3.15
2.3 to 2.6	325 x 325 x 3.15
2.6 to 3.0	350 x 350 x 3.15
3.0 to 3.5	375 x 375 x 3.15
3.5 to 4.5	400 x 400 x 6
4.5 to 5.5	450 x 450 x 6
5.5 to 6.5	500 x 500 x 10
Above 6.5	To be designed

The bracket plate shall be of hexagonal, square or circular contour. The bracket plate shall have fitted at the centre a U-shaped cast iron or mild steel clamp riveted or welded to it. Since the bracket plate carries

the full load of the shutter, it should have sufficient cross-sectional area to resist the shear force and it shall be held in position rigidly by means of suitable foundation bolts. In the case of push and pull shutter, extra tying of the bracket plate to the guide channel is provided by means of a square bar not less than 20 mm size.

This square bar shall be welded on to the back of the guide channel for a length of at least 20 cm. The bracket plate shall then be attached to the top of this square bar by means of 6 mm, countersunk rivets at a spacing of not more than 100 mm. An angle 40 x 40 x 6 mm split at one end is firmly riveted or welded at the top line of the bracket so that this will act as a foundation holdfast. The angle shall extend at least 20 cm from the edge of the bracket plate. This angle is grouted firmly into the wall with the split end of the angle well buried in concrete.

When the bracket is to be fixed on concrete the angle is suitably bent and fixed to the concrete beam or lintel with anchor sleeves and bolts of at least 16 x 75 mm size. A stopper made out of 20 x 6 mm flat is bolted on to the square bar so that the lock plate may be arrested from going beyond the limit.

Roller - The suspension shaft of the roller shall be made of steel pipe conforming to, heavy duty of IS: 116L and of sufficient diameter so as to resist deflection due to the weight of the rolling shutter. The deflection shall not exceed 5 mm per meter width. The recommended sizes of pipes for various widths of rolling shutters/grills are given below; the height of the shutter being limited to a maximum of 5 m. For sizes other than those given below, the size of shaft shall be designed taking into consideration the permissible deflection:

Table 20.3 Recommended sizes of pipes for various widths of rolling shutters

Width	Size of Pipe
Up to 2m	32 mm nominal bore
Up to 2m	40 mm nominal bore
Up to 2m	50 mm nominal bore

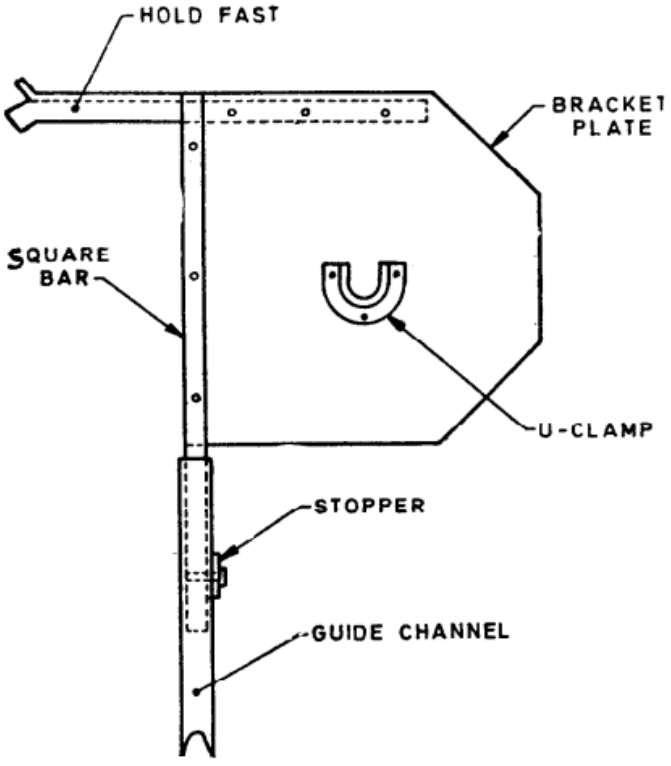

Fig 20.2: Details of Square Bar fixture

The pipes of the suspension shaft which are clamped to the brackets shall be fitted with rotatable cast iron pulleys to which the curtain is attached. The pulleys and the pipe shaft shall be connected by means of pretensioned helical springs to counterbalance the weight of the curtain and to keep the shutter in equilibrium in any partly opened position.

When the width of the opening is greater than 3.5 m, the pulleys shall be interconnected with a cage formed out of mild steel flats of at least 32 x 6 m and mild steel dummy rings made of similar flats so that the torque is distributed uniformly. In such cases, self-aligning two row ball bearings shall be provided with special cast iron casings at the extreme pulleys at either ends. The caging rings shall have a minimum spacing of 15 cm and there shall be at least 4 number flats running throughout the length of the roller.

In the case of shutters for larger openings where the operation of the shutter is carried out using mechanical gear the roller shall be fitted with a pinion wheel at one end which is in contact with a worm fitted to the bracket plate. In this case also the pulleys shall be interconnected with caging with two ball bearings.

Hood Covers - Hood covers shall be made of mild steel sheets not less than 0.900 mm thick. They shall be of hexagonal, square or circular contour depending on the contour of the bracket plate.

The hood cover shall be stiffened with angle or flat stiffeners at top and bottom edges to retain shape. The hood cover shall be fixed to the bracket plate by means of angle cleats and supported at the top at suitable intervals for preventing sagging.

Gears Worms - All gears, worms, etc, used in the assembly of the roiling shutters shall be machine-cut. Worm gear wheels shall be of high grade cast iron or mild steel or phosphor bronze. The worms shall be of mild steel or gun-metal or phosphor bronze.

Fixing Bolts – All fixing bolts shall be of good quality and adequate strength and at sufficiently close pitch to ensure strength and rigidity of the rolling shutter after erection.

Safety Devices - For width up to 2.5 m, a properly fabricated and reinforced bottom lock plate shall be provided to give protection. For widths above 2.5 m, one or both of the safety devices mentioned in 7.9.1 and 7.9.2 o IS 6248 may be provided.

(3) Operation

Self-Coiling Type Rolling Shutters - Self-coiling type rolling shutters shall be raised or lowered manually by means of a puffing hook applied to the pulling handles fixed on the bottom lock plate. The length of the pulling hook shall be adequate to push the bottom lock plate to the topmost position with ease.

Gear-Operated Type Rolling Shutters - Gear-operated type rolling shutters ordinarily employ a worm drive arrangement, the worm driving the worm wheel attached to one end of the roller. Worm drives preferred in view of its irreversible nature, which provides a safeguard against any accidental downward descent of the curtain due to failure of the springs.

Gear-operated type rolling shutters shall be operated: (a) by means of bevel gear box and crank handle or, and (b) by a chain wheel and endless hand chain mounted directly on the worm shaft respectively.

Electrically Operated Rolling Shutters - Electrically operated rolling shutters shall be operated by an electric motor operating on 400/440 V, 3 phase, 50 cycles ac supply. The electric motor shall drive the worm shaft by chain or Vee-belt drive or through a reduction gear box. The reduction gear box shall have a control lever within easy reach from the floor so that the motor may be disengaged and the auxiliary chain gear operating mechanism may be engaged instantly in the event of power failure. The motor unit shall be so mounted that the motor may be completely removed without interfering with the operation of the rolling shutter or the auxiliary drive. The electric drive shall be so designed as to limit the speed of movement of the curtain in either direction to not more than about 10 cm/s.

The controls provided for the electric motor shall include push button control through the medium of a 3-phase reversing starter with interlocking contractors and overload protection. The reversing starter shall be wall-mounted and fitted adjacent to the shutter in a convenient position. A minimum of 3 phase buttons marked ‘Forward ‘, ‘Reverse’ ‘Stop’ or ‘ Up’ ‘Down’ , ‘ Stop ’ shall be provided with a mechanical locking

arrangement to prevent unauthorized or irregular operation of the push buttons. Limit switches shall be provided to cut off current to the motor when the rolling shutter reaches the limit of its travel in the 'Up' and 'Down' directions.

Arrangement shall also be provided for emergency mechanical operation of the rolling shutter in the event of failure of electricity or electrical equipment.

(4) Painting

All component parts of the rolling shutter (excepting springs and the inside of guide channels) shall be given one coat of a brushing quality ready mixed primer conforming to IS: 102-1962 before dispatch. Where a rust inhibiting quality of paint is called for, a zinc chromate primer shall be used. The portions of a rolling shutter where there is contact between aluminium and steel shall be painted with a zinc chromate primer to avoid possibility of corrosion due to electrolytic action as per IS : 1477 (Part I) and IS : 1477 (Part II).

Phosphate treatment may be given prior to painting, if required.

(5) Measurement

Fabrication and fixing of rolling shutter shall be measured in Square metres. Welding, painting, and fixing works shall not be measured separately.

(6) Payment

Fabrication and fixing of rolling shutter shall be paid at the contract unit rates which shall be the full and the final compensation to the Contractor as per Clause 115. Cost for Welding and painting shall deemed to be included in the contract unit rate above.

2004 MS SHEET DOOR

This section lays down the requirements regarding material, type, fabrication, assembly and finish of the double leaf MS Sheet door with angle iron frame.

(1) Material

(a) MS Sheet

The MS sheet of required thickness shall conform to IS 2062:2011 or IS 226:1969 or IS 4351:2003 or equivalent.

All finished steel shall be well and cleanly rolled to the dimensions, sections and masses specified. The finished material shall be reasonably free from surface flaws; laminations; rough/jagged and imperfect edges and all other harmful defects.

(b) Angle Iron

The Angle iron of required dimension for door frame shall conform to IS 4351.

The surface of the door frames manufactured from the material mild steel cold rolled shall be thoroughly cleaned free from rust, dirt, oil, etc, either by mechanical or chemical means.

(c) Gusset Plate

The Gusset plate of required size shall conform to IS 7226 IS 4351.

(d) Other Accessories

Other minor accessories like iron pintels, bolt and nuts, MS hooks, Locking arrangements and handles and rivets shall conform to the respective specifications or equivalent codes.

(2) Welding and Painting

The welding of the components shall conform to IS 816. If specified, the door and its components shall be painted as per IS 1477 or IS 2074 or equivalent.

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(3) Measurement

Fabrication and fixing of MS sheet door of required size shall be measured in Square metres. Welding, painting, and fixing works shall not be measured separately.

(4) Payment

Fabrication and fixing of MS sheet door of required size shall be paid at the contract unit rates which shall be the full and the final compensation to the Contractor as per Clause 115. Cost for Welding and painting shall deemed to be included in the contract unit rate above.

2005 COLLAPSIBLE STEEL SHUTTERS

This section lays down the requirements regarding material, type, fabrication, assembly and finish of the collapsible steel shutters with vertical channel and braced with flat iron diagonals.

(1) Material

Vertical Channels - These shall be hot rolled medium channels of at least 18 x 9 x 3 mm and shall be of weld able quality mild steel conforming to IS: 1977.

Crossings or Lacings - These shall be flats of mild steel of at least 18 X 5 mm size conforming to IS: 1977-1975.

Top and Bottom Runner - Tees or 'E's used for bottom runner shall have minimum web of 40 X 12 mm and flange of 40 x 6 mm, and the flats used for top runner shall be of minimum size 40 x 12 mm. All these shall conform to IS: 1977-1975.

Roller Wheels - These shall be of grey iron castings conforming to grade FG 150 of IS: 210.

Spacer or Sockets - These shall be of cast aluminium conforming to IS: 733.

Rivets - These shall not be less than 6 mm diameter, snap headed, and shall conform to IS: 2155.

(2) Fabrication, Workmanship And Finish

Collapsible gates shall be fabricated from rolled steel channels, T or E sections and flats as shown in Fig. 20.3. These shall be provided with roller wheels at bottom to roll on 'T' or 'E' bottom runners or with wheels at top to roll on flat top runner.

The channels shall have a maximum spacing of 100 mm when the gate is in closed position. The vertical channels shall be first riveted in pairs with toes face to face and with the spacers in position. The crossings shall be introduced at appropriate positions and riveted. One set of crossings shall extend from 450 to 600 mm in height and the clear space between two sets of crossings shall be within 150 mm. The edges shall then be trimmed, locking eyes and handles welded or riveted and the roller wheels fitted in the respective channels.

The number and size of roller wheels shall be dependent on the width of the gate and shall be as given in Table 1 of IS 10521-983. The roller wheels shall be capable of taking the weight of the gate. For gates of width more than 1.5 m and up to 2.0 m, the wheels may be fitted with ball bearings; and for gates of width above 2.0 m, the wheels shall be fitted with ball bearings. Single row ball bearings, self-lubricating type shall be used.

The bottom and top runners shall be fabricated separately with necessary holding fixtures for burying in the ground or fixing in the lintel or to the walls, as the case may be.

Suitable holding fixtures shall be provided for fixing the end channels at the face of the openings. Welding is not required in fabricating the gate except as specified above. All the components shall, therefore, be capable of being dismantled by cutting away the rivets. Maintenance or replacement of worn out parts shall not, therefore, pose any problem.

The fabricated parts shall be finished with a coat of red oxide primer, conforming to IS: 102.

The gate may be provided with safety lever mortice locks. Latches may be provided to hold the channels in position when the gate is in open position.

(3) Measurement

Fabrication and fixing of rolling shutter shall be measured in Square metres. Welding, painting, and fixing works shall not be measured separately.

(4) Payment

Fabrication and fixing of rolling shutter shall be paid at the contract unit rates which shall be the full and the final compensation to the Contractor as per Clause 115. Cost for Welding and painting shall deemed to be included in the contract unit rate above.

2006 TUBULAR TRUSS

This section covers the requirements for hot finished welded (HFW), hot finished seamless HFS), and electric resistance welded (ERW) or high frequency induction welded (HRIW) plain carbon steel tubes for tubular truss.

(1) Material

The tubes shall be manufactured from steel as given in Table 20.4 and shall be supplied in the conditions as shown therein.

Table 20.4

SN	Manufacturing Process	Steel	Supply Condition
1	HFW	IS 10748	Only YSt210 or YSt240
2	HFS	Bars/ingots with suitable chemical composition as per IS 10748 to achieve mechanical proper ties for respective grades	YSt210, YSt240 or YSt310
3	ERW/HRIW	IS 10748	YSt210, YSt240 or YSt310 as welded, heat treated or cold drawn and normalized

(2) Dimension, Weight and Tolerances

The standard sizes and weights, geometrical properties of tubes for structural purposes shall be as given in Table 1 of IS 1161.

Tubes of thickness lower than light tubes, specified in Table 1 of IS 1161 shall not be permissible. The following tolerances shall apply:

a) Outside Diameter:

1) Up to and including 48.3 mm: +0.4mm
-0.8mm

2) Over 48.3mm: ±1 Percent

b) Thickness (for all sizes):

1) Welded tubes: +Not limited
-10 percent

2) Seamless tubes: + Not limited
- 12.5 percent

c) Weight:

1) Single tube light:	+ 10 percent - 8 percent
Medium Heavy	± 10percent
2) 10 tonne lots light:	±5 percent
Medium Heavy	± 7.5percent

Straightness

Unless otherwise agreed to between the purchaser and the manufacturer, tubes shall not deviate from straightness by more than 1mm in any 600 mm length.

Lengths

The tubes shall normally be supplied in random lengths at 4 to 7 m. If ordered in exact lengths, the tolerances shall be subject to prior agreement.

(3) Workmanship

The tubes shall be cleanly finished and reasonably free from scale. They shall be free from cracks, surface flaws, laminations and other defects. The ends shall be cut cleanly and square with the axis of tube, unless otherwise specified. Surface imperfections such as handling marks, light die or roll marks, or shallow pits shall not be considered as defects provided the imperfections are removable within minimum wall thickness permitted.

Removal of such surface imperfections is not required. Welded tubing shall be free of protruding metal on the outside surface of the weld seam.

(4) Galvanizing and Painting

If the tubes are required in galvanized condition the zinc coating on the tubes shall be conforming to the requirements and tested as per methods, specified in IS 4736.

All tubes shall, unless otherwise specified, be varnished, painted or oiled externally.

(5) Mechanical Test

The following tests shall be carried out on the selected tube, strip or plate. For mechanical tests, tubes shall be sampled in accordance with IS 4711.

(a) Tensile Test

The tensile strength, the yield stress and the percentage elongation shall be determined in accordance with the methods specified in IS 1608 and shall be not less than the values specified for the relevant grades of tubes given in Table 20.5.

Table 20.5 Tensile Properties of Steel Tubes for Structural Purposes

Grade	Tensile Strength (Min)	Yield Stress *(Min)*	Elongation on Gauge Length Min. Percent
YSt 210	330	210	20
YSt 240	410	240	17
YSt 310	450	310	14

NOTES

- *1 MPa =1N/mm^2= 0.102 kgf/mm^2*
- *Elongation percent for tubes up to and including 25 mm nominal bore for all grades shall be 12 minimum*

(b) Ductility Test

(i) Cold Bend Test (Up to and Including 50 mm NB)

When tested in accordance with IS 2329 an unfilled length of tube shall be capable of being bent cold by tube bending machine around a grooved former (with radius at bottom of the groove equal to 6 x O. D. of the tube) through 180° (with weld at 90° to the plane of bending) without showing any crack at the weld or the metal.

(ii) Flattening Test (Tubes Above 5Omm NB)

Rings, not less than 40 mm in length cut from the ends of selected tubes with edges rounded shall be flattened between parallel plates with the weld, if any, at 90° (point of maximum bending) in accordance with IS 2328. No opening shall occur by fracture in the weld until the distance between the plates is less than the value specified for each grade in co1 4 of Table 20.6 and no cracks or breaks in the metal elsewhere than in the weld shall occur until the distance between the plates is less than the value specified for each grade in col5 of Table 20.6.

Table 20.6 Flattening Requirement in Metal

SN	Manufacturing Process Metal	Steel Grade	Weld (Distance Between the plates)	Parent (Distance Between the plates)
1	HFW/HFS/ERW/HFIW	YSt 210	75 percent of OD	60 percent of OD
2	HFW/HFS/ERW/HFIW	YSt 240	85 percent of OD	75 percent of OD
3	FHS/ERW/HFIW	YSt 310	85 percent of OD	75 percent of OD

(6) Measurement

Providing and fixing of tubular truss shall be measured in Kilograms. Welding, painting, and fixing works shall not be measured separately.

(7) Payment

Providing and fixing of tubular truss shall be paid at the contract unit rates which shall be the full and the final compensation to the Contractor as per Clause 115. Cost for Welding and painting shall deemed to be included in the contract unit rate above.

2007 GI BARBED WIRE FENCING

This section covers the requirements for galvanized steel barbed wire with Timber, Concrete or Angle Iron post for fencing purpose.

(1) Material

(a) GI Barbed Wire

The galvanized barbed wire shall be manufactured from mild steel wire conforming to IS 280. The galvanized coating shall conform to the requirements for any one of the type of coating as given in IS 4826 as per requirement. The coating requirements of electrogalvanized wire shall conform to the requirements for any one of the type as given in IS 12753. The sizes of barbed wire shall be as given in Table 20.5.

Table 20.5 Sizes of Barbed wire

SN	Size Designation	Diameter of Wire				Mass of Completed Barbed Wire		Distance Between Two Barbs mm	No. of Lays Between the Two Consecutive Barbs
		Line Wire		Point Wire					
		Nominal mm	Tolerance mm	Nominal mm	Tolerance mm	Max g/m	Min g/m		
i)	1	2.50	±0.08	2.50	±0.08	155	136	75 ± 12	2 to 7
ii)	2	2.50	±0.08	2.50	±0.08	120	108	150 ±12	2 to 7
iii)	3	2.50	±0.08	2.00	±0.08	125	108	75 ± 12	2 to 7
iv)	4	2.50	±0.08	2.00	±0.08	103	89	150 ±12	2 to 7
v)	5	2.24	±0.08	2.00	±0.08	106	97	75 ± 12	2 to 7
vi)	6	2.24	±0.08	2.00	±0.08	85	78	150 ±12	2 to 7

- **Manufacture**

The barbed wire shall be formed by twisting together two-line wires, one or both containing the barbs. The direction of twisting may be in one direction or alternately in left or right directions.

The barbs shall be so finished that the four points are set and located or locked as far as possible at right angles to each other. The barbs shall be well formed, tightly wrapped and shall have a length of not less than 13 mm and not more than 18 mm. The point shall be sharp and cut at an angle not greater than 35° to the axis of the wire forming the barbs.

- **Chromating**

The barbed wire may also be given protective chromate conversion coating as per requirement. This shall conform to IS 1340.

- **Freedom from Defects**

The line and point wires shall be circular in section, free from scales and other defects and shall be uniformly galvanized. The line wire shall be in continuous lengths and shall not contain any welds other than those in the rod before it is drawn. The distance between two successive welding's in the line wire of finished barbed wire shall not be less than 15 m. There shall be no splicing.

- **Test**

The manufactured GI barbed wire shall be tested in accordance to IS 278.

(b) Timber

The timber post used for fencing shall comply with requirements of IS 3386. Timber shall be free from permissible defects and well-seasoned as per IS 1141 to a moisture content not more than 18 percent within a depth of 10 mm from the surface when measured anywhere in middle one-third length of the post.

The materials used, type of post, their dimensions, manufacturing process, preservative treatment and painting, erection of pole, foundation works and spacing of poles shall comply with IS 3386.

(c) RCC Post

The RCC post used for fencing purpose shall comply with IS: 4996. Materials, manufacturing process, shape and dimensions, tolerances, recommendations for the provisions of wire holes and their spacing, as well as the erection of post and wire fence along with foundation works also shall comply with IS: 4996.

(d) MS Angle Iron

The MS Angle Iron used for post in fencing works shall comply with IS 808.

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(e) Concrete

Concrete used in fencing works (foundation works) shall comply with Section 800.

(2) Measurement

Different GI barbed wire fencing works shall be measured in linear meter as specified in the contract document. Painting, timber post, concrete post shall not be measured separately. However, earthwork in excavation for foundation and foundation concrete shall be measured separately for payment.

(3) Payment

Different GI barbed wire fencing works shall be paid at the contract unit rates which shall be the full and the final compensation to the Contractor as per Clause 115. Cost for painting, timber post, concrete post shall be deemed to be included in the contract unit rate above. However, earthwork in excavation for foundation and foundation concrete shall be paid separately as per the contract unit rate specified in respective chapters.

2008 STOP LOG GATES

This section covers the requirements for the stop logs which acts as a temporary closure for openings on various types of structures like intakes, canal check structures, spillways, and diversion works.

(1) Material

The materials recommended to be used for different components is given in Appendix A of IS: 5620 or equivalent.

(2) Measurement

Stop log gate works shall be measured in metric ton as specified in the contract document.

(3) Payment

Stop log gate works shall be paid at the contract unit rates which shall be the full and the final compensation to the Contractor as per Clause 115. Cost for Cutting, Welding, Fitting, Fixing, Painting and rubber seal shall be deemed to be included in the contract unit rate above.

2009 SINGLE SCREW SPINDLE GATE (FOR SMALL GATES IN SMALL AND MEDIUM IRRIGATION CANALS)

(1) Scope

This section covers the requirements for the Single screw spindle gate to be used in small and medium irrigation canals (Cross and Head Regulator) manually.

(2) Material

The material for different component of the gate shall be as follows:

(a) Skin Plate

The thickness of skin plate shall be as specified in the design drawing with the contract document. The thickness of skin plate shall not be less than 8mm in any case. Material recommended for the skin plate shall be as per IS: 226 or equivalent.

(b) MS Angle

The size of MS Angle shall be as specified in the design drawing with the contract document. The section of MS Angle shall not be less than 40mm*40mm*5mm in any case. The MS Angle of required dimension for Single Screw Spindle gate shall conform to IS 4351.

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(c) MS Plate

The thickness of MS plate shall be as specified in the design drawing with the contract document. The thickness of MS plate shall not be less than 5mm in any case. Material recommended for the MS plate shall be as per IS: 226 or equivalent.

(d) MS Channel

MS Channel shall be ISMC 100 conforming to high grade mild steel.

(e) Threaded Spindle

The diameter of Threaded Spindle shall be as specified in the design drawing with the contract document. The diameter of Threaded Spindle shall not be less than 50 mm in any case. Material recommended for the Threaded Spindle shall be as per IS: 3042 or equivalent.

(f) Screw Spindle Hoist (Gear box)

The operating gear shall consist of a hand operated self-sustaining gear capable of operating the gate against the maximum wider loading conditions specified, and capable of positively holding the gate in any position when the hand wheel or crank handle is released. The operating gear shall be capable of being operated by one man.

The gear units shall consist of a bronze operating nut engaging with a mild steel operating screw attached to the gate. All gear sprockets and pinions shall be machine cut with ratio and strength adequate of withstand operating loads. Gears shall be enclosed with casings to avoid dust and rain. To prevent unauthorized use, operating gear shall be provided with appropriate locking devices. The lift housing or hand wheel shall be provided with a cast-in direction arrow and the word “OPEN” to indicate the direction of operation, to open gates.

Lift mechanisms shall be provided with a cast iron stop nut to allow adjustable end stop travel.

(g) Nut Bolt and Washer

The Nut Bolt and Washer shall be as specified in the design drawing with the contract document. Material recommended for the Nut and bolt shall be mild steel conforming to IS: 1367 or equivalent and washer shall be Synthetic or Natural Vulcanized Rubber conforming to Grade 6 of IS: 5192 or equivalent.

(3) Welding and Painting

Contractor shall perform all required welding and painting works as specified in the drawing. The welding of the components shall conform to IS 816. If specified, the gates and its components shall be painted as per IS 1477 or IS 2074 or equivalent.

(4) Measurement and Payment

Single Screw Spindle Gate shall be measured in square metres or metric ton as specified in the contract document. Single Screw Spindle Gate shall be paid at the contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115. Cost for Welding, Painting, Nut bolt, Washer and rubber seal shall be deemed to be included in the contract unit rate above.

2010 SINGLE SCREW SPINDLE GATE (FOR HEAD REGULATOR, CROSS REGULATOR AND ESCAPE IN LARGE CANALS)

(1) Scope

This section covers the requirements for the Single screw spindle gate to be used in large irrigation canals (Head Regulator, Cross Regulator and Escape) manually.

(2) Material

The material for different component of the gate shall be as follows:

(a) Skin Plate

The thickness of skin plate shall be as specified in the design drawing with the contract document. The thickness of skin plate shall not be less than 8mm in any case. Material recommended for the skin plate shall be as per IS: 226 or equivalent.

(b) MS Plate

The size and thickness of MS plate for various use such as side girder, vertical stiffener, seal base plate, seal clamp plate, etc. shall be as specified in the design drawing with the contract document. The thickness of MS plate shall not be less than 5mm in any case. Material recommended for the MS plate shall be as per IS: 226 or equivalent.

(c) Indian Standard Mild Steel Beam and Channels

Indian Standard Mild Steel Beam (ISMB) and Indian Standard Mild Steel Channels (ISMC) of different section shall be used for various use in Gate leaf structure, embedded parts and Superstructure and Platform as per design drawings conforming to high grade mild steel.

(d) Main Roller Assembly

Main roller assembly to be used in gate leaf structure shall comprise all its components as specified in the design drawing and they should be of required standard and quality acceptable to the Engineer.

(e) Single Screw Spindle Hoist

The operating Single Screw Spindle Hoist shall consist of a hand operated self-sustaining gear capable of operating the gate against the maximum wider loading conditions specified, and capable of positively holding the gate in any position when the hand wheel or crank handle is released. The operating Single Screw Spindle Hoist shall be of 1 ton capacity capable of being operated by one man. Single Screw Spindle Hoist shall comprise all its components and each component shall be of standard quality acceptable to the Engineer.

(f) Nut Bolt and Washer

The Nut Bolt and Washer shall be as specified in the design drawing with the contract document. Material recommended for the Nut and bolt shall be mild steel conforming to IS: 1367 or equivalent and washer shall be Synthetic or Natural Vulcanized Rubber conforming to Grade 6 of IS: 5192 or equivalent.

(3) Welding and Painting

Contractor shall perform all required welding and painting works as specified in the drawing. The welding of the components shall conform to IS 816. If specified, the gates and its components shall be painted as per IS 1477 or IS 2074 or equivalent.

(4) Measurement and Payment

Single Screw Spindle Gate shall be measured in square metres or metric ton as specified in the contract document. Single Screw Spindle Gate shall be paid at the contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115. Cost for Welding, Painting, Nut bolt, Washer and rubber seal shall be deemed to be included in the contract unit rate above.

2011 MOTORISED DOUBLE SCREW SPINDLE GATE

(1) Scope

This section covers the requirements for the motorized operated double screw spindle gate to be used in large irrigation system.

(2) Material

The material for different component of the gate shall be as follows:

(a) Skin Plate

The thickness of skin plate shall be as specified in the design drawing with the contract document. The thickness of skin plate shall not be less than 10 mm in any case. Material recommended for the skin plate shall be as per IS: 226 or equivalent.

(b) MS Plate

The size and thickness of MS plate for various use such as side girder, vertical stiffener, seal base plate, seal clamp plate, etc. shall be as specified in the design drawing with the contract document. The thickness of MS plate shall not be less than 8 mm in any case. Material recommended for the MS plate shall be as per IS: 226 or equivalent.

(c) Indian Standard Mild Steel Beam and Channels

Indian Standard Mild Steel Beam (ISMB) and Indian Standard Mild Steel Channels (ISMC) of different section shall be used for various use in Gate leaf structure, embedded parts and Superstructure and Platform as per design drawings conforming to high grade mild steel.

(d) Main Roller Assembly

Main roller assembly to be used in gate leaf structure shall comprise all its components as specified in the design drawing and they should be of required standard and quality acceptable to the Engineer.

(e) Double Screw Spindle Hoist Motorized

The operating Double Screw Spindle Hoist motorized shall consist of two screw spindles power operated self-sustaining gear capable of operating the gate against the maximum wider loading conditions specified, and capable of positively holding the gate in any position as required. The operating Double Screw Spindle Hoist motorized shall be of 2.5 ton capacity capable of being operated by motor. Double Screw Spindle motorized hoist shall comprise all its components and each component shall be of standard quality acceptable to the Engineer.

(f) Nut Bolt and Washer

The Nut Bolt and Washer shall be as specified in the design drawing with the contract document. Material recommended for the Nut and bolt shall be mild steel conforming to IS: 1367 or equivalent and washer shall be Synthetic or Natural Vulcanized Rubber conforming to Grade 6 of IS: 5192 or equivalent.

(3) Welding and Painting

Contractor shall perform all required welding and painting works as specified in the drawing. The welding of the components shall conform to IS 816. If specified, the gates and its components shall be painted as per IS 1477 or IS 2074 or equivalent.

(4) Measurement and Payment

Power operated Double Screw Spindle Gate shall be measured in square metres or metric ton as specified in the contract document. Motorized Double Screw Spindle Gate shall be paid at the contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115. Cost for Welding, Painting, Nut bolt, Washer and rubber seal shall be deemed to be included in the contract unit rate above.

2012 MOTORIZED DOUBLE ROPEDRUM HOIST GATE

(1) Scope

This section covers the requirements for the motorized operated double rope drum hoist gate to be used in large irrigation system.

(2) Material

The material for different component of the gate shall be as follows:

(a) Skin Plate

The thickness of skin plate shall be as specified in the design drawing with the contract document. The thickness of skin plate shall not be less than 10 mm in any case. Material recommended for the skin plate shall be as per IS: 226 or equivalent.

(b) MS Plate

The size and thickness of MS plate for various use such as side girder, vertical stiffener, seal base plate, seal clamp plate, etc. shall be as specified in the design drawing with the contract document. The thickness of MS plate shall not be less than 8 mm in any case. Material recommended for the MS plate shall be as per IS: 226 or equivalent.

(c) Indian Standard Mild Steel Beam and Channels

Indian Standard Mild Steel Beam (ISMB) and Indian Standard Mild Steel Channels (ISMC) of different section shall be used for various use in Gate leaf structure, embedded parts and Superstructure and Platform as per design drawings conforming to high grade mild steel.

(d) Main Roller Assembly

Main roller assembly to be used in gate leaf structure shall comprise all its components as specified in the design drawing and they should be of required standard and quality acceptable to the engineer.

(e) Motorized Double Rope drum Hoist

The Motorized Double Rope drum Hoist shall consist of two rope drum power operated self-sustaining gear capable of operating the gate against the maximum wider loading conditions specified, and capable of positively holding the gate in any position as required. The Motorized Double Rope drum Hoist shall have Central drive unit (Motor (1.1 kW sq. cage induction moto), worm gearbox (35:1 worm gearbox), motor coupling, base frame, transmission shaft and couplings, fixing bolts) and two Rope drum hoist units. Each Rope drum unit shall have Rope drum (Rope drum with PCD 250mm), cylindrical gear and pinion sets (1st gear/ pinion PCD= 450 /100 mm), intermediate gear and pinion set (2nd gear/ pinion PCD = 450/100 mm), bearings, base frame). Motorized Double Rope drum Hoist shall comprise all its required components and each component shall be of standard quality acceptable to the Engineer.

(f) Nut Bolt and Washer

The Nut Bolt and Washer shall be as specified in the design drawing with the contract document. Material recommended for the Nut and bolt shall be mild steel conforming to IS: 1367 and washer shall be Synthetic or Natural Vulcanized Rubber conforming to Grade 6 of IS: 5192.

(3) Welding and Painting

Contractor shall perform all required welding and painting works as specified in the drawing. The welding of the components shall conform to IS 816. If specified, the gates and its components shall be painted as per IS 1477 or IS 2074 or equivalent.

(4) Measurement and Payment

Power operated double rope drum hoist gate shall be measured in square metres or metric ton as specified in the contract document. Motorized double rope drum hoist gate shall be paid at the contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115. Cost for Welding, Painting, Nut bolt, Washer and rubber seal shall be deemed to be included in the contract unit rate above.

2013 CHAIN LINK FENCING

(1) Material

G.I. Chain link fabric fencing of required width in mesh size 25 mm x 25 mm or specified otherwise of approved brand and made of specified dia GI wire of specified thickness / or not as specified in item of required colour or shade shall be used for fencing. GI wire may be PVC coated if specified in BoQ. Angles

and black pipes to be used for fencing work shall be of standard quality as approved by Engineer.

(2) Fixing

GI chain link shall be stretched and fixed in specified width, strengthening with 2mm dia wire or nuts bolts & washers as required to be done complete as per the direction of Engineer. GI chain link shall be enclosed in Angle frame of specified dimension using black pipe of specified diameter at specified spacing as mentioned in BoQ.

(3) Measurement and Payment

The length and width of completed work of chain link fencing shall be measured correct to a cm. The area shall be calculated in square meter, correct to two places of decimal. The payment shall be made at unit rate as specified in BoQ and shall include the cost of material and labour involved in all the operations described above. Payment shall be full and the final compensation to the Contractor as per Clause 115.

2014 CHICKEN MESH FENCING

(1) Material

MS bar Chicken mesh fencing of required size in mesh size 62 mm x 62 mm or specified otherwise of approved brand and made of specified dia MS bar shall be used for fencing. Angles and black pipes to be used for fencing work shall be of standard quality as approved by Engineer.

(2) Fixing

Chicken mesh shall be fixed in specified width, as required to be done complete as per the direction of Engineer. MS bar Chicken mesh shall be enclosed in Angle frame of specified dimension using black pipe of specified diameter at specified spacing as mentioned in BoQ.

(3) Measurement and Payment

The length and width of completed work of chicken mesh fencing shall be measured correct to a cm. The area shall be calculated in square meter, correct to two places of decimal. The payment shall be made at unit rate as specified in BoQ and shall include the cost of material and labour involved in all the operations described above. Payment shall be full and the final compensation to the Contractor as per Clause 115.

2015 SPIRAL RAZOR BLADE FENCING

(1) General

Spiral razor blade fencing, often referred to as "razor wire," is a type of security fencing made from sharp, barbed wire coils. The design typically features sharp blades that deter unauthorized access and enhance security. It can be installed on walls, fences, or concertina coils for added security.

(2) Material

It should be made from robust materials to withstands weather conditions and wear. Razor wire shall be made from hot dip galvanized steel, stainless steel 304, or stainless steel 316.

(3) Fixing

The coil of spiral razor blade fencing is available in different dimensions. The specific coil shall be used as mentioned in BoQ. The razor blade fencing shall be fixed on the ground, walls, fences, or concertina coils as required for safety desired. It shall be fixed using angle post, binding wire, clamps, nut and bolts, etc as designed and specified in the drawing.

(4) Measurement and Payment

The length of completed work of Spiral razor blade fencing shall be measured correct to a cm. The payment shall be made at unit rate as specified in BoQ and shall include the cost of material and labour involved in

all the operations described above. Payment shall be full and the final compensation to the Contractor as per Clause 115.

SECTION 2100: PIPE AND SEWER LAYING

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2101 PIPE CANALS, DRAINS AND PIPE CULVERTS

(1) Scope

This section covers the works for the construction of pipe canals, drains and culverts with prefabricated reinforced cement concrete pipes, high density polythene pipes (HDP Pipes), Double Wall Corrugated (DWC) HDPE Pipe, Cast Iron (CI) pipe, Galvanized Iron (GI) Pipes or Stoneware glazed pipes.

(2) Materials

(a) Reinforced Concrete Pipes

Reinforced concrete pipes shall be NP2 or NP3 as specified in the contract or on the drawing and shall comply with the requirements of NS: 80 /IS: 458.

Reinforced concrete pipes either spun or vibrated cast shall be such that the maximum tensile stress in the circumferential steel due to specified hydrostatic test pressure does not exceed the limit of 125 N/mm^2 in the case of mild steel rods, 140 N/mm^2 in the case of hard-drawn steel wires and high strength deformed steel bars and wires. Hydrostatic Pressure is the maximum pressure which the pipe can withstand without any leakage when tested for hydrostatic pressure in accordance with IS 3597.

The barrel thickness shall be such that under the specified hydrostatic test pressure, the maximum tensile stress in concrete, when Considered as effective to take stress along with the tensile reinforcement shall not exceed 2 N/mm ^{2} for pressure pipes and 1.5 N/mm ^{2} for non-pressure pipes. But the barrel wall thickness shall be not less than those given in Table 21.1, 21.2 and 21.3 for specified pipes manufactured by specified process as per IS 458:2003.

Table: 21.1: Design and Strength requirements of Concrete Pipes of class NP2 Reinforced Concrete, Light duty, Non- Pressure Pipes.

Internal diameter of pipes mm	Barrel Wall thickness mm	Reinforcements			Strength, Test requirement forThree edge Bearing Test	
		Longitudinal, mildsteel or hard drawnsteel		Spiral , Hard drawnsteel Kg/ Linear metre	Load to produce 0.25 mm Crack KN/ Lin metre	Ultimate Load KN/ Linmetre
		Minimum number	Kg/ Linear metre			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
150	25	6	0.59	0.24	10.79	16.19
200	25	6	0.59	0.38	11.77	17.66
225	25	6	0.59	0.46	12.26	18.39
250	25	6	0.59	0.58	12.55	18.83
300	30	8	0.78	0.79	13.48	20.22
350	32	8	0.78	1.13	14.46	21.69
400	32	8	0.78	1.49	15.45	23.18
450	35	8	0.78	1.97	16.18	24.27
500	35	8	0.78	2.46	17.16	25.74
600	45	8	0.78	3.47	18.88	28.32
700	50	8	1.22	4.6	20.35	30.53
800	50	8	1.22	6.71	21.57	32.36
900	55	8	1.22	9.25	22.80	34.20
1000	60	8	1.76	10.69	24.27	36.41

1100	65	8	1.76	12.74	25.50	38.25
1200	70	8	1.76	15.47	26.97	40.46

Table: 21.2: Design and Strength requirements of Concrete Pipes of class NP3 Reinforced Concrete, medium duty, Non- Pressure Pipes.

Internal diameter of pipes mm	Barrel Wall thickness mm	Reinforcements			Strength, Test requirement for Three edge Bearing Test	
		Longitudinal, mildsteel or hard drawnsteel		Spiral , Hard drawnsteel Kg/ Linmetre	Load to produce 0.25 mm Crack KN/ Lin metre	UltimateLoad KN/ Linmetre
		Minimum number	Kg/ Linear metre			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
300	40	8	0.78	1.8	15.5	23.25
450	75	8	0.78	3.79	21.56	32.34
600	85	8 or 6+6	1.18	7.01	28.74	43.11
900	900	6+6	2.66	18.30	43.11	64.67
1000	115	6+6	2.66	21.52	47.90	71.85
1200	120	8+8	3.55	33.57	57.48	86.22

Table 21.3: Design and Strength Test requirements of Concrete Pipes of class NP3-Reinforced concrete, Medium duty, Non-pressure made by vibrated Casting process.

Internal diameterof pipes mm	Barrel Wall thickness mm	Reinforcements			Strength, Test requirement for Three edge Bearing Test	
		Longitudinal, mildsteel or hard drawn steel		Spiral , Hard drawnsteel Kg/ Linmetre	Load to produce 0.25 mm Crack KN/ Lin metre	Ultimate Load KN/ Linmetre
		Minimum number	Kg/ Linear metre			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
300	50	8	0.78	1.53	15.5	23.25
450	65	8	0.78	1.9	21.56	32.34
600	75	8 or 6+6	1.18	2.2	28.74	43.11
900	100	6+6	2.66	11.55	43.11	64.67
1000	115	6+6	2.66	15.70	47.90	71.85
1200	125	8+8	3.55	21.25	57.48	86.22

(b) HDPE Pipes

HDPE pipes, if required to be supplied shall comply with the requirements of NS: 40 or IS 4984-1995. The material used for the manufacture of pipes should not constitute toxic hazard, should not support microbial growth and should not give rise to unpleasant taste or odour, cloudiness or discoloration of water. Pipes shall be classified according to the grade of materials as given in Table 21.4 and followed by pressure rating (Table 21.5) and nominal diameter.

Table 21.4 Classification of Pipe material

SN	Material Grade	MRS(Minimum Required Strength) of Material in MPa, at 20 °C, 50 Years	Maximum Allowable Hydrostatic Design Stress (σ), MPa	
			At 20 °C	At 50 °C
1	PE80	8	6.3	5.0
2	PE100	10	8	6.3

Table 21.5 Classification of Pipe by Pressure Rating

Pressure Rating of Pipe	Maximum Permissible Working Pressure (MPa)
PN 2.5	0.25
PN 4	0.40
PN 6	0.60
PN 10	1.00
PN 12.5	1.25
PN 16	1.60

The specified base density shall be between 940.5 kg/m3 and 946.4 kg/m3 (both inclusive) when determined at 27°C according to procedure prescribed in Annex A of IS 7328: 1992. The value of the density shall also not differ from the nominal value by more than 3 kg/m3 as per **5.2.1.1** of IS 7328: 1982.

The percentage of anti-oxidant used shall not be more than 0.3 percent by mass of finished resin. The anti-oxidant used shall be physiologically harmless and shall be selected from the list given in IS 10141: 1982.

The outside diameters of pipes, tolerance of the same and ovality of pipe shall be as given in Table 2 of IS 4984:1995. The minimum and maximum wall thickness of pipes for the different grades of materials, namely PE 63, PE 80 and PE 100 shall be as given in Tables 3, 4 and 5 respectively in IS 4984:1995.

The internal and external surfaces of the pipes shall be smooth, clean and free from grooving and other defects. The ends shall be cleanly cut and shall be square with axis of the pipes. Slight shallow longitudinal grooves or irregularities in the wall thickness shall be permissible, provided that the wall thickness remains within the permissible limits.

(c) Cast Iron (CI) pipe

Cast iron pipe if required to be supplied shall comply with this specification. The metal used for the manufacture of pipes shall be of good quality (not less than that specified for Grade FG 150 of IS 210:1978), commensurate with the mechanical requirements as per IS 8329:2000. It shall be manufactured by any method at the discretion of the manufacturer provided that the requirements defined in IS 8329:2000 are met. The pipes and fittings shall be stripped with all precautions to avoid warping or shrinkage defects, detrimental to their good quality. The pipes and fittings shall be free from defects, other than any unavoidable surface imperfections which result from the method of manufacture and which do not affect the use of the fittings.

The pipes and fittings shall be such that they could be cut, drilled or machined and may be accepted provided the hardness of the external un-machined surface does not exceed 210 HBS.

CI pipes shall comply with the test and requirements of IS 8329:2000, IS 1536:2001, IS 1537:1976, IS 1538:1993 and IS 3114:1994.

(d) Galvanized Iron Pipes

GI pipe if required to be supplied shall comply with this specification. GI pipes (tubes) shall be galvanized mild steel hot finished seamless (HFS) or welded (ERW) HRIW or HFW screwed and socketed conforming to the requirements of IS 1239 Part-1 for light, medium & heavy grade. They shall be of the diameter (nominal bore) specified in the description of the item, the sockets shall be designated by the respective nominal bores of the pipes for which they are intended.

Galvanizing shall conform to IS 4736:1986. Zinc containing at least 98.5 percent by mass should be used

for the purpose of galvanizing, or the molten metal in galvanizing bath shall contain not less than 98.5 percent by mass of zinc. The zinc coating shall be uniform adherent, reasonably smooth and free from such imperfections as flux, ash and dross inclusions, bare batches, black spots, pimples, lumping runs, rust stains bulky white deposits and blisters. The pipes and sockets shall be cleanly finished, well galvanized in and out and free from cracks, surfaces flaws, laminations and other defects. All screw threads shall be clean and well cut. The ends shall be cut cleanly and square with the axis of the tube. The test for galvanization shall be carried out as per IS 4736:1986 or equivalent.

Steel tubes covered by this standard shall be classified as light, medium and heavy depending on the wall thickness. Specifications of light, medium and heavy pipes as per IS 1239 Part 1, shall be as below:

Table 21.6 Dimensions and Nominal mass of Steel Tubes-Light

Nominal Bore	Outside Diameter		Thickness	Mass of Tube	
	Maximum	Minimum	mm	Plain End	Screwed and Socketed
Mm	mm	mm	mm	Kg/m	Kg/m
(1)	(2)	(3)	(4)	(5)	(6)
6	10.1	9.7	1.8	0.360	0.363
8	13.6	13.2	1.8	0.515	0.519
10	17.1	16.7	1.8	0.670	0.676
15	21.4	21.0	2.0	0.947	0.956
20	26.9	26.4	2.3	1.38	1.39
25	33.8	33.2	2.6	1.98	2.00
32	42.5	41.9	2.6	2.54	2.57
40	48.4	47.8	2.9	3.23	3.27
50	60.2	59.6	2.9	4.08	4.15
65	76.0	75.2	3.2	5.71	5.83
80	88.7	87.9	3.2	6.72	6.89
100	113.9	113.0	3.6	9.75	10.0

Table 21.7 Dimensions and Nominal mass of Steel Tubes-Medium

Nominal Bore	Outside Diameter		Thickness	Mass of Tube	
	Maximum	Minimum	mm	Plain End	Screwed and Socketed
Mm	mm	mm	mm	Kg/m	Kg/m
(1)	(2)	(3)	(4)	(5)	(6)
6	10.6	9.8	2.0	0.404	0.407
8	14.0	13.2	2.3	0.641	0.645
10	17.5	16.7	2.3	0.839	0.845
15	21.8	21.0	2.6	1.21	1.22
20	27.3	26.5	2.6	1.56	1.57
25	34.2	33.3	3.2	2.41	2.43
32	42.9	42.0	3.2	3.10	3.13
40	48.8	47.9	3.2	3.56	3.60
50	60.8	59.7	3.6	5.03	5.10
65	76.6	75.3	3.6	6.42	6.54
80	89.5	88.0	4.0	8.36	8.53
100	115.0	113.1	4.5	12.2	12.5
125	140.8	138.5	4.8	15.9	16.4
150	166.5	163.9	4.8	18.9	19.5

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Table 21.8 Dimensions and Nominal mass of Steel Tubes-Heavy

Nominal Bore	Outside Diameter		Thickness	Mass of Tube	
	Maximum	Minimum	mm	Plain End	Screwed and Socketed
Mm	mm	mm	mm	Kg/m	Kg/m
(1)	(2)	(3)	(4)	(5)	(6)
6	10.5	9.8	2.6	0.487	0.490
8	14.0	13.2	2.9	0.765	0.769
10	17.5	16.7	2.9	1.02	1.03
15	21.8	21.0	3.2	1.44	1.45
20	27.3	26.5	3.2	1.87	1.88
25	34.2	33.3	4.0	2.93	2.95
32	42.9	42.0	4.0	3.79	3.82
40	48.8	47.9	4.0	4.37	4.41
50	60.8	59.7	4.5	6.19	6.26
65	76.6	75.3	4.5	7.93	8.05
80	89.5	88.0	4.8	9.90	10.1
100	115.0	113.1	5.4	14.5	14.8
125	140.8	138.5	5.4	17.9	18.4
150	166.5	163.9	5.4	21.3	21.9

The pipe shall be supplied in standard lengths of 6 meters each. Each pipe shall be provided with a corresponding size of one socket at one end and a plastic ring (cover) at the other end for protection of the threads of the pipes. Non-standard lengths shall be approximately 3 meters in length or as required by the purchaser. One socket to be provided with each pipe at one end and a plastic ring on the other end as mentioned above. All screwed tubes shall be supplied with pipe threads conforming to IS 554. Unless specified otherwise, tubes shall be supplied screwed with taper threads and fitted with one socket having parallel thread. The socket shall conform to all requirements (except 6.4) of IS 1239 (Part 2).

The tolerance on pipe wall thickness and outside diameter of the pipes shall comply with Section 2.4 of BS 1378 or Section 9 of IS1239 or equivalent.

The tensile strength shall be at least 320 MPa (320 N/mm²). The test shall be carried out on full section or strip cut from the selected tubes in accordance with IS 1608 and IS 12278.

When tested in accordance with IS 2329 the tubes shall be capable of withstanding the bend test without showing any signs of fracture or failure. Welded tubes shall be bent with the weld at 90° to the place of bending. The tubes shall not be filled for this test.

Each pipe and fittings shall be tested at the place of manufacture to a hydraulic test pressure or 50 bar (MPa) without showing defects of any kinds, the pressure being maintained sufficiently long (in any case not less than three minutes) for proof and inspection.

(e) Double Wall Corrugated HDPE

Double Wall Corrugated HDPE pipe if required to be supplied shall comply with this specification. Double Wall Corrugated (DWC) HDPE pipes are similar to normal HDPE pipes except that they have different external corrugated surface & internal smooth surfaces which gives them additional strength and stiffness. These are made with High Density Polyethylene which has very high life expectancy (75 to 100 years). These are available from 75 mm to 1.0 m internal diameter with standard length of 6 meters. These pipes are light weight and can be used for non-pressure underground sewerage, drainage & cross drainage (pipe culvert) including rain water harvesting purposes.

These pipes shall have simple push fit joints with Elastomeric sealing Ring for on-line system or with extra couplers. They shall be chemically inert to waste water ingredients with no chance of corrosion. The Pipe shall be checked visually for ensuring good workmanship that the ducts shall be free from holes, breaks and other defects. The ends shall be cleanly cut and shall be square with axis of the ducts and shall be evaluated for their safety against rodents and resistance to external influences (dust and water) before

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laying them in the fields.

The DWC HDPE pipes shall be tested to conform to the IS 16098 (Part 2): 2013 and IS 14930 Part I and II.

(f) Stoneware Glazed Pipe

Stoneware Glazed Pipe if required to be supplied shall comply with this specification. All pipes and fittings shall be sound and free from visible defects which impair the strength, durability and serviceability. The glaze of pipes and fittings shall be free from crazing. The pipes and fitting shall give a sharp clear note when struck with a light hammer. The interior and exterior surfaces of the pipes and fittings which remain exposed after jointing, shall be glazed. The portion which remains covered after jointing may or may not be glazed. The pipes shall be tested to leakage, absorption test, acid resistance, alkali resistance test and crushing strength test conforming to IS 3006 – 1979.

Pipes and fittings shall be tested for acid and loss in mass shall not exceed 2.5 percent. Pipes and fittings shall be tested to the action of magnesium sulphate and no evidence of pitting, softening, spalling or cracking in the pipe or fitting after the test. The pipes should have minimum crushing strength of 16 KN/m which further increases as per pipe dia and class as per IS 651. The permissible variation for internal diameter of pipe shall be 3 to 12mm as per its respective diameter as per to IS 3006 – 1979.

Sand, Cement and Jute required for joining the pipes shall be fresh and of good quality. Cement and Sand shall comply with the requirements of these items specified in Section 800. Jute to be used for pipe joints shall be free from foreign materials and should have long fiber to ensure high strength, flexibility and integrity of pipe joints.

(g) Slotted pipe

Slotted Pipe if required to be supplied shall comply with this specification. Slotted pipes are pipes with slots cut into them in a pattern suitable to the basic material of the pipe. The slotted pipes shall be made of either corrosion-resistant material or steel pipes having sufficient thickness to guard against the effect of corrosion and to ensure reasonable life of tube well. The following are the recommended materials for various types of slotted pipes:

a) Low carbon or mild steel;

b) Leaded brass sheet (see IS: 531);

c) Fiber glass reinforced thermosetting plastics;

d) PVC (see IS 10151(PVC for contacts with food , pharma and drinking water) and IS 12818(PVC pipes for bore/ tubewell)

e) Copper wire (see IS: 4412), galvanized steel wire (see IS: 280) and stainless-steel wire (see IS: 6528).

The shapes and size of the slot shall be such that the gravel or aquifer material is not allowed to block the open space and result in plugging. Sharp edges on the periphery of the pipe may offer resistance to flow and hence it is preferable to have smooth rounded edges. The normal slot size shall be 1.0, 1.6, and 3.2 mm. The shape of slot shall be inwardly widening to give no clogging property and shall have minimum resistance to water flow. The slots shall be cut in a pattern designed to get even distribution of flow all over the periphery of the pipe.

The tolerances on the dimensions and slot opening on pipes and the method for different test on pipe and slots shall comply to IS 8110:2000. The guidelines for selection of slot size is given in Annex B of IS 8110:2000.

(3) Excavation for pipe

The foundation bed for the pipe culverts/drains shall be excavated in accordance with Section 300 true to the lines and levels shown on the Drawing or to such other lines and depths as the Engineer may direct. The pipes shall be placed in shallow excavation of the natural ground or in open trenches cut in existing embankments, taken down to the levels as shown on the Drawing. The additional width of the trench on

either sides of the pipe shall be 150 mm or one-fourth of the diameter of the pipe whichever is more. Should the Contractor desire to use mechanical plant for excavating trenches or for laying pipes he shall submit his proposals for approval by the Engineer, but such approval shall not relieve the Contractor from his responsibilities in case of damage to pipes.

The pipe shall be placed where the ground for the foundation is reasonable firm. Where the bottom of the trench as excavated does not provide a suitably firm foundation for the culvert, due to soft, mucky or other unsuitable material being encountered, the unsuitable material shall be excavated to such depth, width and length as directed by the Engineer. The excavation shall then be backfilled with gravel or other approved granular material which shall be properly shaped and thoroughly compacted up to the specified level.

(4) Timbering Pits and Trenches

The sides of trenches shall, where required, be adequately timbered and supported to the satisfaction of the Engineer. All such excavations shall be of sizes sufficient to enable the pipes and concrete to be laid accurately and the formwork withdrawn before refilling and ramming is carried out.

(5) Water in Excavation

Trenches shall be kept free form water until the pipes are installed and the joints have hardened. The Contractor shall, at his own expense, construct any sumps or temporary drains that the Engineer may consider necessary. The Contractor shall make good at his own expense, any damage caused by prolonged and excessive pumping, and shall take all precautions necessary for the safety of adjoining structures by shoring or otherwise, during the time the trenches are excavated.

(6) Laying and Jointing Pipes

Arrangement for handling lifting, loading, transporting, unloading, storage and lowering the pipes in bed shall be such that the pipes do not suffer any damage.

The pipes shall be laid true to line and level, commencing from the outfall. No pipes shall be laid until it has been approved by the Engineer. Pipes shall be laid such that each one is in contact with the bed throughout the length of barrel. The pipes shall be laid closely together against each other so as to obtain tight joints.

Where two or more pipes are to be laid adjacent to each other, they shall be separated by a distance equal to half the diameter of the pipe subject to a minimum of 450 mm.

Concrete pipe culverts shall be laid on granular bedding or concrete bedding or as shown on the Drawing.

The concrete pipes shall be jointed either by collar joint or flush joint as specified in the contract or on the drawing. In case of collar joint, the collar shall be of reinforced cement concrete 150 to 200 mm wide according to the diameter of the pipe and having the same structural strength as the pipes to be jointed. Caulking space shall be between 13 to 19 mm according to the diameter of the pipe as specified by NS: 80/ IS: 458 caulking material shall be slightly wet mix of cement and sand in the ratio of 1: 2 rammed with caulking irons. Before caulking, the collar shall be placed such that its center coincides with the joint and an even annular space is left between the collar and the pipe. In case of flush joint, the ends of the pipes shall be spaced to from a self-centering joint with a joining space of 13 mm side. The jointing space shall be filled with cement sand mortar in the ratio of 1:2 after packing fibrous jute. Cares shall be taken to fill all voids and to see that any excess of cement mortar is neatly cleaned off while each joint is being made and any earth, cement or other material thoroughly cleaned out of the pipes. All joints shall be made with care so that the interior surface is smooth and consistent with the interior surface of the pipes. After finishing, the joint shall be kept covered and damped for at least four days. A properly fitted plug shall be well secured at the end of each pipes already laid and shall be removed only when next pipe is being laid or on completion of the culvert or drain. The trench shall be kept free from water until the joint are thoroughly set. Jointing of HDP pipes shall be done by heating as prescribed by the manufacturer. Joining of other pipes shall be as specified in the contract or on the drawing.

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(7) Cement Mortar for Jointing

Cement mortar for jointing pipes shall consist of one part by weight of Portland cement to two parts by weight of sand. Sand shall comply with Sub-clause 602 (2) of section 600. The materials shall be accurately gauged and mixed in an approved manner. Cement mortar shall be made in suitable small quantities only and when required, and any mortar which has begun to set or which has been mixed for a period of more than the initial setting time shall not be used.

(8) Pipe to be left Clean on Completion

On completion, all pipe lines, drains etc., shall be flushed from end to end with water and left clean and free from obstructions.

(9) Pipes Bedding and Encasing

Pipes shall be laid on granular or concrete bedding or as shown on the Drawing.

(a) Granular Bedding

The pipes shall be laid on a layer of fine granular material, 100 mm thick, after the bottom of excavation has been shaped to conform to the lower part of the pipe as shown on the Drawing. The bedding material shall be well graded granular material passing 5.6 mm sieve and suitably compacted.

(b) Concrete Bedding

Where indicated on the Drawing, the pipes shall be laid on grade M 10/40 concrete confirming to Section 800 so that the bottom of the pipe rests on concrete of the specified thickness. The thickness of the concrete below the pipe and the height to which it extends upwards shall be as indicated on the Drawing.

(c) Concrete Encasing

Where shown on the Drawing, pipes shall be fully encased in concrete as shown on the Drawing. The grade of the concrete shall be as shown on the Drawing. In carrying out this work the Contractor shall take care to pack the concrete under and around the pipes to ensure even bedding and solidity in the concrete; in no instance shall the concrete be thrown directly on the pipes. The concrete shall be placed in such a way that all spaces around the pipe are completely filled with concrete. Concrete casing shall be cast in one continuous operation until completed. The upper surface of the concrete shall be struck off with a wooden screed to avoid honeycomb and neatly finished off.

(10) Joining New Work to Old Work

Where partial demolition is required for extension to the existing structures, the contact face shall be cut to predetermined lines and levels. The loose and fragmented material shall be removed and projecting steel cleaned and bent as directed by the Engineer. Where no partial demolition but only extension is required, the contact area shall be roughened and cleaned of all dirt and loose particles.

(11) Refilling Trenches

Backfill for pipes and minor drainage structure shall be obtained from the material excavated during excavation. In the event of there being insufficient excavated material or the culvert is laid close to or above existing ground level then selected backfill shall be obtained from borrow pits. All backfill whether from excavated material or borrow pits shall be suitable material as defined in Clause 302 and shall have a CBR of at least 5% measured after 4 days soak on laboratory mix compacted to 93% MDD (Heavy Compaction), plasticity Index of less than 35%, maximum particle size of 40 mm and shall be compacted to a dry density of 93% MDD (Heavy Compaction)

For pipe culvert which have been placed and where no concrete haunch or surround is called for, selected fill of suitable material available from the excavation shall be place in layers not exceeding 150 mm of loose thickness. The material shall be uniformly mixed with water or dried out such that the moisture content at the time of compaction is between 95% and 100% of the Optimum Moisture Content. Then it shall be compacted thoroughly. Similar selected material shall then be laid in layers, not exceeding 150 mm of loose thickness, mixed, dried or watered as necessary and carefully compacted, and brought up uniformly

on both sides of the pipe up to a height of not less than 300 mm over the crown. The remaining of the trench shall then be backfilled with suitable materials, placed in layers not exceeding 150 mm of loose thickness, mixed, watered or dried as necessary and carefully compacted. All backfilling material except the top 300 mm below formation level shall be compacted to a minimum dry density of 93% of MDD (Heavy Compaction). The top 300 mm below formation level shall be placed in layers not exceeding 150 mm of loose thickness, mixed, watered or dried as necessary and carefully compacted to at least 95% of MDD (Heavy Compaction).

For pipe culverts which have been constructed close to, above or where the culverts protrudes above the existing ground the backfilling under the flanks and alongside and over the culverts shall be placed and compacted in layers not exceeding 150 mm to a density of at least the density required for the material in adjoining layers of fill. All existing ground under this backfill shall be compacted to 93% MDD (Heavy Compaction) to a depth of 150 mm.

Backfilling shall be carried out simultaneously and equally on both sides of the culvert to avoid unequal lateral forces. In all cases there shall be cover of at least 600 mm over the crown of the culvert before construction equipment is driven over it unless protective measures approved by the Engineer have been provided.

(12) Inlet and Outlet Structures and Catch pits

Catch pits, headwalls, wing walls, aprons and other ancillary works required to be constructed as per the nature of the structure and site condition shall be constructed in accordance with the details shown on the Drawing. Masonry for these works shall conform to Section 600 or 700 as applicable. Concrete shall conform to Section 800 and aprons shall conform to Section 1500.

(13) Opening to Traffic

In case of pipe culvert, no traffic shall be allowed to cross the pipeline unless the height of the filling is not more than 600 mm above the top of the pipe line or is as shown on the Drawing.

(14) Tests and Standard of Acceptance

The Contractor shall submit manufacturer's test certificate for each lot of pipes required to be supplied. The test result shall meet the requirements of the Specifications.

Backfilling/Refilling shall be tested in accordance with Section 300 and all the test result shall meet the criteria specified. Compaction shall be tested in each layer of backfill, gradation of granular bedding shall be tested at least once a day and the test results shall meet the specified criteria.

The pipe drains/culverts and other pipe laying works for different purposes shall be constructed to the true lines and levels as indicated on the Drawing or instructed by the Engineer.

(15) Measurement

Pipes laying shall be measured along their center between the inlet and outlet ends in linear meters of individual pipe element of each size, completed and accepted in place. Collar, in case of concrete pipe laying shall not be measured for payment as its cost is deemed to be included in its unit rate. Excavation, bedding, concrete for encasing and backfilling works shall be measured separately in cubic metres. Ancillary works such as head walls, wing walls, etc., shall be measured as provided for in the respective Sections of these Specifications. Different pipe fittings as specified in contract or on the drawing shall be measured in numbers.

(16) Payment

Different pipes laying and fittings shall be paid at their respective contract unit rates specified in the Bill of Quantities of the contract, which shall be the full and the final compensation to the Contractor as per Clause 115.

2102 WEEP HOLES USING HDPE PIPES

(1) Weep holes

Weep holes using HDPE pipes wrapped in Geotextiles in the mouth (on the fill side) shall be provided in solid plain concrete/reinforced concrete, brick/stone masonry, abutment, wing wall, return walls or other structures as shown on the Drawing or as directed by the Engineer. Weep holes shall be provided in the structures with 75mm dia polythene pipe. Weep holes shall extend through the full width of concrete/masonry with a slope of 1 vertical 20 horizontal towards the draining face. The spacing of weep holes shall generally be 1 m in either direction or as shown on the drawing with the lowest at about 150 mm above the low water level or ground level whichever is higher or as directed by the Engineer. Surfaces of the weep holes shall be smooth and it shall be ensured that the water is properly driven from the backfill. Materials of HDPE pipe and geotextiles used for making weep holes in the structures shall be of the acceptable quality as mentioned in this specification.

(2) Measurement

Unless otherwise specified, Weep holes shall not be measured separately. If weep holes are specified as separate item in the contract or on the drawing, these shall be measured in number. No deduction in the volume of structures shall be made for weep holes.

(3) Payment

Unless otherwise specified, Weep holes shall not be paid separately. The contract unit rate for respective items shall be deemed to include costs for providing such holes. If weep holes are specified as separate item in the contract or on the drawing, these shall be paid at the respective contract unit rate specified in Bill of Quantities of the contract.

SECTION 2200: ROADWORKS

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2201 GENERAL

This section covers the overall requirements and works related to the construction of road and other related works.

2202 ROADWORKS OVERALL REQUIREMENTS

Those requirements, which are related to the roadworks mentioned under this section 2200 shall be applicable.

A. Construction Control Testing/Process Control Testing

Unless otherwise directed, values given in these Specifications are minimum values for the properties of materials and the workmanship. They shall be considered satisfactory, if all results of the tests, taken at the frequencies specified, are at least equal to the values given in the relevant Section of these Specifications.

B. Tolerances

(i) Horizontal Alignments

Horizontal alignments shall be determined from the centerline of the pavement surface as shown or calculated from the Drawing. The centerline of the pavement surfaces as constructed, and all other parallel alignments, shall be correct within a tolerance as specified in Table 22.1.

Table 22.1: Tolerances for Horizontal Alignment

Functional Class of Road	Centre line of pavement	Edge of carriage way	Edge of road way
Class I (ADT > 20000 PCU)	±10mm	±15mm	±25mm
Class II (ADT 5000- 20000 PCU	±20mm	±30mm	±50mm
Class III (ADT 2000-5000 PCU	±30mm	±45mm	±75mm
Class IV (ADT < 2000 PCU	±40mm	±40mm	±100mm

(ii) Width of Pavement

The average width of pavement layer measured at five conjugative points at every 200 m in any Section shall be as specified in Table 22.1.

(iii) Thickness of Pavement Layers

The average thickness of any pavement layer measured at five conjugative points at every 20 m in any Section shall not be less than the thickness specified nor more than 120% of the thickness specified or directed by the Engineer.

(iv) Surface Levels

The level measured at any point on the levels of the subgrade and different pavement courses as constructed, shall not vary from those calculated with reference to the longitudinal and cross profile of the road shown on the drawings or as directed by the Engineer beyond the tolerance mentioned in Table 22.2.

For checking compliance with the requirement of Table 22.2 measurements of surface levels shall be taken on a grid of points placed at 12.5 m centers longitudinally and at 2m transversely. At junctions, the grid point's spacing shall be as determined by the Engineer.

For any 10 consecutive measurements taken longitudinally or transversely, not more than one measurement shall be permitted to exceed the tolerance as in table 22.2., this one measurement being not

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in excess of 5 mm above the permitted tolerance.

Table 22.2: Tolerances for Level

SN		Class I	Class II	Class III	Class IV
1	Subgrade	±20 mm	±30 mm	±40 mm	±50 mm
2	Sub base a. Flexible pavement b. Concrete pavement	 ±10 mm ± 6 mm	 ±15 mm ±10 mm	±20 mm	±25 mm
3	Base course for flexible pavement a. Bituminous Base/ Binder course b. Granular i) Machine laid ii) Manually laid	 ± 6 mm ±10 mm ±15 mm	 ±10 mm ±15 mm ±20 mm	 ± 15mm ±20 mm ±25 mm	 ±25 mm ±30 mm
4	Wearing course for Flexible Pavement i) Machine laid ii) Manually laid	 ±6 mm ±10 mm	 ±10 mm ±15 mm	 ±15 mm ±20 mm	 ±20 mm ±25 mm
5	Cement concrete Pavement	±5 mm	±10 mm	±10 mm	±10 mm

However, the negative tolerance for wearing course shall not be permitted in conjunction with the positive tolerance for base course, if the thickness of the former is thereby reduced by more than following limits;

- 4 mm for bituminous wearing course of thickness 40 mm or more
- 3 mm for bituminous wearing course of thickness 40 mm or less
- 5 mm for concrete pavement slab

(v) Surface Regularity

The longitudinal profile bituminous concrete shall be checked with 3-meter-long straight edge/ moving straight edge as directed by the Engineer at the middle of each traffic lane along a line parallel to the center line of the road.

The maximum permitted number of surface irregularities shall be as per Table22.3.

Table 22.3: Maximum permitted number of surface irregularities

	Surface of Carriageways and Paved shoulders				Surface of Laybys, Service Areas and all Bituminous base course			
Irregularity	**4 mm**		**7 mm**		**4 mm**		**7 mm**	
Length (m)	300	75	300	75	300	75	300	75
Number of Surface Irregularities on Class I roads	15	9	2	1	40	18	4	2
Number of Surface Irregularities on Class II, III, IV roads	40	18	4	2	60	27	6	3

The maximum allowable difference between the road surface and underside of a 3 m straight edge when placed parallel with, or at right angles to the centre line of the road at points decided by the Engineer shall be a per Table 22.4.

Table 22.4: Tolerance for Surface Regularity

SN		Class I	Class II	Class III	Class IV
1	Subgrade	±15 mm	±20 mm	±30 mm	±40 mm
2	Granular Base / Sub base course under Concrete pavement	±8 mm ±10 mm	±12 mm ±10 mm	±15 mm 10 mm	±20 mm 10 mm
3	Bituminous Base course	± 6 mm	±10 mm	±15 mm	
4	Pavement surface (Asphalt/ Cement concrete)	±5 mm	±10 mm	±10 mm	±10 mm

If tolerances given in Table 22.2 for level and straight edge are not in agreement, in that case the tolerances

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given for straight edge shall prevail.

The tolerances for level and surface regularity as given in Table 22.2, 22.3 and22.4 shall be applicable only for new construction, Re-construction and Rehabilitation works. These shall be not applicable in case of resealing by surface dressing/sand seal/ slurry seal in existing paved road.

(vi) Riding Quality

The riding quality of bituminous concrete / Asphalt concrete wearing surface, as measured by a standard Bump integrator or other roughness measuring instrument as directed by the Engineer, shall not be more than 2000 mm per Km.

(vii) Shoulders

Shoulders shall be constructed to the same requirements of thickness, level and surface regularity as for the adjacent pavement layers.

(viii) Cuttings and Embankment Slopes

In final trimmed slope of cuttings or embankment a tolerance of +0.25 shall be permitted, i.e. if a slope of 1 in 2 is specified, the acceptable slope shall be not steeper than 1 in 2 or slacker than 1 in 2.25.

(ix) Width of Cutting and Embankments

The tolerance permitted in the width of the bottom of cutting shall be 200 mm between the centerline of the road and the toe of the cutting slope.

The width of embankments measured horizontally and perpendicular to the centerline of the road at the top of the embankment shall not be less than shown on the Drawing or more than that shown on the Drawing plus 50 mm.

(x) Depth of Side Drains

The depth of road side drain shall be as specified in the drawing. The difference between road level measured at the center line of the road and that of the bottom of the side drain measured perpendicular to the center line of the road shall not deviate from the specified in the drawing by ± 25 mm.

C. Rectification of Earthworks and Pavement Layers Exceeding Tolerances

Where any tolerances in Sub-clause 2202 (B) are exceed, the Contractor shall assess the full extent of the area which is out of tolerances and shall make good the surface of the pavement course, earthworks or formation either by removing or by replacing the material and reworked.

D. Measurement and Payment

The Contractor shall be deemed to have included his rates and prices for the cost of complying with the requirements of Clause 2202.

Notwithstanding the provisions of Sub-clauses 2202 (B) and 2202 (C) measurement and payment for earthworks and pavement works shall be made on the basis of the net-cross section directed by the Engineer or as shown on the Drawing. No additional payment shall be made for any variation. If the executed work is within the limit of tolerance, but less than the specified-on drawing or directed by the Engineer, the payment shall be made for actual quantity executed, if the executed work is more, the payment shall be made for as shown on the drawing or directed by the Engineer.

2203 ADVERSE WEATHER WORKING

(1) No material in frozen condition shall be incorporated in the works, but it shall remain on site for use, if suitable when unfrozen.

(2) Laying of material containing bitumen, or mixture thereof, shall cease under the following adverse conditions:

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a. during foggy and rainy weather;
b. when rain is imminent

(3) While the air temperature is rising, work may be performed at the temperatures of;

- 6° Celsius with a wind velocity of 25 km/hr.
- 10° Celsius with a wind velocity of 55 km/hr.

(4) When the air temperature is falling, works must be stopped as soon as temperature reaches 6° Celsius regardless of wind velocity. It shall not be resumed until the temperature is definitely rising.

(5) When strong wind is blowing and this is likely to interfere with the proper execution of the work, no surfacing, especially spraying of binder shall be done.

(6) Concrete shall not be placed during falling temperatures when the ambient falls below 7° Celsius or during rising temperatures when the ambient temperature is below 3° Celsius. The temperature of the placed concrete shall not be allowed to fall below 5 degree Celsius until the concrete has thoroughly hardened. When necessary, concrete ingredients shall be heated before mixing but cement shall not be heated.

When the ambient air temperature exceeds 40° Celsius during the concreting operation, the Contractor shall take measures to control the temperature of the ingredients. Such measures shall include spraying the aggregates stockpile with water to promote cooling down by evaporation and, where feasible, shading of stockpiles and the area where concreting is carried out, reducing time between mixing and placing, and restricting concreting as far as possible to early morning and late evenings. Curing shall commence after placing of the concrete in order to prevent excessive loss of moisture.

2204 USE OF SURFACES BY CONSTRUCTION TRAFFIC

The loads and intensity of construction traffic used on pavements under construction shall be regulated so that no damage is caused to sub-grade and pavement layers already constructed.

The wheels and track of plant moving over various pavement courses shall be kept free of deleterious materials.

Bituminous base course shall be kept clean and uncontaminated as long as it remains uncovered by a wearing course and surface treatment. Should the base course or tack/prime coat become contaminated, the Contractor shall make good by cleaning it to the satisfaction of the Engineer, including removal of the contaminated layer and replacing it as per the requirements of these Specifications which shall be done by the Contractor at his own risk and cost.

2205 CARE OF WORKS

The general obligations for “Care of the Works” shall inter-alia include the following:

Material shall not be spread on a layer that is wet and may damage it during compaction of subsequent layer or when opened to traffic.

When material is spread out on the road, it shall, be given a good cross-fall and a light compaction on the surface with a steel-tire roller, in order to facilitate run-off during rainy weather.

All completed works in a layer shall be protected and maintained until the subsequent layer is placed. Maintenance shall include immediate repairs to any damage or defects, which may occur and shall be repeated as often as is necessary to keep the layer continuously intact and in a good condition.

Before priming any completed layer or placing a subsequent layer thereon, any damage to the existing layer shall be repaired so that after repair or reconstruction, if necessary, it shall conform in all respects to the requirements specified for that layer.

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All repair work other than repairs of minor surface damages shall be inspected and tested before covering up.

The previously constructed layer shall also be thoroughly cleaned of all foreign material before construction of a succeeding layer. In the case of bituminous work, the existing layer shall be thoroughly broomed and all dung, clay, mud and other deleterious and loose material shall be removed.

Where necessary, the surface shall be sprayed with water before, during and after brooming to remove all foreign material.

Roads shall not be made dirty as a result of construction of works, transportation of equipment, plants, labor and/or materials. In the case of becoming dirty, they shall be cleaned immediately.

The provision of temporary drainage works such as drains, open channels, bank etc. and the furnishing and operation of temporary pumps and such other equipment as may be necessary to adequately drain, protect and de-water the Works and Temporary works. This will be in addition to any permanent drainage works specified and installed, and in addition to any temporary drainage works specifically paid for separately.

Care shall be exercised not to allow material in borrow pits to become excessively wet, to keep all completed layers properly drained, to avoid dumps of material on completed layer work that shall inhibit surface drainage or from wet spots under and around dumps, and to protect all parts of the Works against erosion by floods and rain

Fill and cut slopes shall be promptly repaired whenever damaged by surface water

Excavation for pipes drains, culverts, service ducts and similar structure shall be adequately protected against possible ingress of water during rainstorms.

The Contractor shall inform the Engineer of damage or defect to any work before repair or maintenance and the Engineer shall instruct the extent and method of repair. The previously constructed layer shall be thoroughly cleaned of all foreign material and the Contractor shall request its inspection by the Engineer before construction of the following layer or application of prime coat, surfacing or surface treatment. In the case of all bituminous work in particular the existing layer shall be thoroughly broomed and all dung, clay, and other deleterious material completely removed. Where necessary the surface shall be sprayed with water before, during and after brooming to remove all foreign material.

2206 MEASUREMENT AND PAYMENT

No measurement and payment shall be made for the works required under the clauses 2203, 2204 and 2205. All costs in connection with the requirements specified herein shall be deemed included in the rates and prices of the related items of works in the Bill of Quantities.

2207 SUBGRADE

A. SCOPE

This Section deals with the treatment of the upper layers of earthworks including preparation and surface treatment of the formation, the addition of layers of selected material, the improvement of in-situ materials by addition and mixing of selected materials or by addition and mixing of lime if required.

B. DEFINITIONS

(1) Formation Level

The level of the top surface of the subgrade upon which pavement structures is built up.

(2) Subgrade

Up to 500 mm below formation (Lowest level of pavement crust) level is designated as “subgrade”.

(3) Capping Layers

Capping layers are layers of specified materials to be laid and compacted in the subgrade and below as required, in replacement of in-situ materials to achieve CBR.

(4) California bearing ratio (CBR)

California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of natural ground, subgrades and base courses beneath new carriageway construction.

C. SITE CLEAREANCE AND PREPARATION OF SUBGRADE

The site clearance shall be carried out manually using tools like spade, pick and hand shovel. Mechanical equipment like dozer, scrapper and ripper, if required may be used for this purpose.

Preparation and surface treatment of formation shall be carried out only after completion of all site clearance and drainage works unless otherwise agreed by the Engineer and prior to laying the sub base or the base where no sub base is required. The sequence of operations shall be as follows:

(1) Formation of Loose Untreated Materials

All subgrade material shall be from sources, which the contractor shall propose and which shall be approved by the Engineer. Materials for use in the subgrade shall not contain particles larger than 60 mm. In addition, the material shall have a CBR of not less than 5% measured after a 4-day soak on a laboratory mix compacted to 95% MDD (heavy compaction), a swell of less than 1%, a plasticity index of less than 40% and an organic matter content less than 3%. In-situ material in the subgrade in cutting that does not meet these requirements shall either be spoiled or, if suitable, placed in the embankment. The spoiled material shall be replaced with material meeting the requirements for loose material in the subgrade.

In fill areas, and in cutting except otherwise instructed by the Engineer, according to the material encountered, loose materials of the embankment and cuttings shall be deposited in the layers of 150 mm compacted depth. Each layer shall extend reasonably more than the full width of the embankments or cutting and shall be compacted in accordance with requirements as specified hereunder: -

a. The material shall be broken down to the above specified grading and any oversize material which cannot be broken down to the require size shall be removed and disposed off. The material shall be scarified and the moisture content shall be adjusted by either uniformly mixing in water or drying out the material such that the moisture content during compaction is between 95% and 100% of the Optimum Moisture Content. The moisture content shall be kept within these limits until compaction is complete except where otherwise instructed by the Engineer.
b. Each layer shall be compacted to a dry density equal to at least 95% MDD (heavy compaction).
c. In accordance with specification, the Contractor shall submit to the Engineer his proposals for the compaction of the material to be used in the subgrade. The proposal shall be based on the type of plant, the range of passes and the loose depth of the layer.
d. The Contractor shall carry out site compaction trials, supplemented by necessary laboratory investigations, and shall satisfy the Engineer that all the specified requirements regarding compaction shall be achieved.
e. Site compaction trials shall be completed and approved by the Engineer before the permanent Works commences.
f. Testing to be carried out during the construction of subgrade shall include the following:

    (i) The MDD (heavy compaction), Field density and OMC shall be determined for each new material encountered as specified in Table 8.8. The test of field density shall be conducted in staggered manner i.e. at left, at crown and at right in the carriageway.

    (ii) The soaked CBR of material in the subgrade shall be determined as per Table 8.8 for each layer.

The Contractor shall request in writing for the Engineer's approval for each layer in accordance with specification and such request shall be accompanied by the tests results of the above-described testing and all additional relevant information required. If the results are as specified, he will approve for addition

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of another layer or will ask for further tests or rework to meet the requirements.

(2) Formation in Rock Cutting

The subgrade in rock cutting shall be regulated after trimming the rock excavation by a regulating course of minimum 150 mm compacted depth of natural material complying with the requirements of natural material for sub base as per clause 2208.

The regulating course shall be laid, compacted and tested in accordance with Clause 2208 and the surface regularity shall meet the requirements of Clause 2202.

(3) Formation in Ordinary Soil Cutting

The subgrade in ordinary soil cutting shall be made after cutting the soil to the required level. Any undulation heap or depression shall be regulated after trimming the heap and filling the depression by a regulating course of minimum 150 mm compacted depth of natural material complying with the requirements of natural material for sub base as per clause 2208.

The regulating course shall be laid, compacted and tested in accordance with Clause 2208 and the surface regularity shall meet the requirements of Clause 2202.

(4) Formation in GBM soil Cutting

The subgrade in GBM soil cutting shall be made after cutting the GBM soil to the required level. Any undulation heap or depression shall be regulated after trimming the heap and filling the depression by a regulating course of minimum 150 mm compacted depth of natural material complying with the requirements of natural material for sub base as per clause 2208.

The regulating course shall be laid, compacted and tested in accordance with Clause 2208 and the surface regularity shall meet the requirements of Clause 2202.

(5) Surface Regularity and Tolerances

The surface regularity and tolerance of the subgrade shall meet the requirements of Clause 2202. When each layer is completed, the Contractor shall comply with the requirements for requesting the Engineer's approval and protecting the layer.

D. CAPPING LAYER

Where shown on the Drawing or where in-situ material in the subgrade in cutting does not meet the requirements, in-situ materials shall be replaced with selected material from cuttings or borrow pits.

Where materials of differing quality are available for placing in the embankments, the Engineer may also instruct that certain materials should be excluded from the subgrade and that certain materials should be set apart or obtained from borrow pits for use in the upper layers.

When materials for subgrade are extracted from borrows to form the capping layers they shall be natural material complying with the following requirements: -

(1) Material classification

Materials used for use in capping layers shall be selected among soils classified as GW, GP, GC, and SW in the General Classification of Soils.

(2) Material Requirements

Material for use in the capping layers shall not contain particles larger than 75 mm and their percentage passing by weight the 0.075 mm sieve shall be less than 15%. The material shall have a CBR of not less than 15% measured after a 4-day soak on a laboratory mix compacted to 95 % MDD (heavy compaction), a swell of less than 1%, a plasticity index of less than 12%.

(3) Laying and Compaction

The material shall be deposited in the layer of 150 mm compacted depth. Each layer shall extend over the full width of the embankments or cutting and shall be compacted in accordance with the requirements specified in Sub-clause 2207(C).

(4) Tolerances

Tolerances of capping layers shall be in accordance with Sub-clause 2207(C) (4). When each layer is completed, the Contractor shall comply with specification for requesting the Engineer's approval and protecting the layer.

E. WATERING

As the strength of subgrade materials is influenced by compaction and moisture content, consideration should be given during design to the likely construction densities and moisture conditions specified for the construction of the subgrade.

If watering is necessary to bring the mixture to the required moisture content, this shall be done after spreading water uniformly. Water shall be added in a uniform and controllable manner and, where necessary, in successive increments. Concentration of water at any point or a flow of water over the surface shall be avoided.

Any part of the subgrade which becomes too wet for compaction shall be allowed to dry out until its moisture content is satisfactory for compaction.

F. COMPACTION

If the Drawings require the subgrade to be compacted for a depth greater than 150mm, the work shall be carried out in more than one layer, the material in the upper layer being first removed in the case of road sections in cut.

The moisture content of the sub-grade material before compaction shall be within ±2% of the predetermined optimum moisture content. The achieved dry density after compaction of the subgrade layer shall not be less than 98% of maximum dry density.

When necessary, each layer, before being compacted, shall be allowed to dry or be watered to bring the moisture content to within ±2% of optimum to make possible its compaction to the required dry density. The material shall be so worked as to have a uniform moisture content through the entire layer. Where the subgrade is in embankment, the subgrade layers to the required depth shall be compacted to achieve dry density not be less than 95% of maximum dry density (MDD) determined earlier in accordance with Modified Proctor Test.

The subgrade material shall be compacted uniformly by use of adequate and appropriate compaction equipment. The compaction shall be done in a longitudinal direction along the embankment and shall generally begin at the outer edges and progress toward the centre in such a manner that each section receives equal compactive effort.

If the test results show that the density is less than the required dry density, the Contractor shall carry out further compaction to obtain at least the required dry density. The compacted subgrade layer shall be approved by the Engineer before the Contractor can commence a new layer. The surface of the finished subgrade shall be neat and workmanlike and have the required form, super elevation, levels, grades and cross section.

The finished surface shall be constructed with a tolerance of 20 mm above or below the specified levels at any point. Samples to determine the compaction shall be taken regularly with a set of three samples for each 1,000 square meters of finished layer or as decided by the Engineer will be carried out. If the surface fails to meet the requirements of this Specification, the Contractor shall take the action set out in the appropriate part of Clause 2202 or such other action as the Engineer may instruct, or agree.

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G. MEASUREMENT

(1) Subgrade construction of specified thickness with loose untreated materials, formation in ordinary soil cutting, formation in GBM Soil cutting shall be measured in square meter by measuring the average width and length of the road section at intervals of 10 meters or as directed by the Engineer.

(2) Capping layer shall be measured in square meter for specified thickness as described in contract.

(3) Rolling/Compaction works shall be measured in cubic meter.

(4) Water sprinkling work shall be measured in metric Tonne.

H. PAYMENT

The subgrade construction with loose untreated materials, formation in ordinary soil cutting, formation in GBM Soil cutting, capping layer, Rolling/Compaction works and Water sprinkling work shall be paid at their respective contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115.

2208 GRANULAR SUBBASE

A. Scope

This Clause covers the construction of subbase with naturally occurring quarzitic gravel, river gravels (Sand mixed gravel) and transported gravels, broken stone or materials resulting from the weathering of rocks, or clayey/silty sand.

B. Sources of Materials

The material to be used for the work shall be natural river bed sand and gravel, stone dust, crushed gravel and crushed (Broken) stone, crushed slag or combination thereof depending upon the grading requirement.

Subbase materials shall be obtained from approved sources in borrow or cut or from such other sources of supply as may be specified or approved from time to time for use.

The Contractor shall comply with all requirements of borrow pits or other source specified.

C. Material Requirements

The material shall be free from organic or other deleterious constituents and shall confirm to the grading given in Table 22.5 and physical Requirement 22.6. Grading's III and IV shall preferably be used in lower sub-base. Grading's V and VI shall be used as sub-base cum drainage layer. Where the sub-base is laid in two layers as upper sub- base and lower sub-base, the thickness of each layer shall not be less than 100 mm. Grading to be adopted for a project shall be as specified in the Contract.

Table 22.5: Grading Envelope for Granular subbase material

Sieve Size As per IS designation (mm)	Percentage passing by weight					
	Grading I	Grading II	Grading III	Grading IV	Grading V	Grading VI
75	100				100	
53	80-100	100	100	100	80-100	100
26.5	55-90	79-90	55-75	50-80	55-90	75-100
9.5	35-65	50-80			35-65	55-75
4.75	25-55	40-65	10-30	15-35	25-50	30-55

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2.36	20-40	30-50			10-20	10-25
0.85					2-10	
0.425	10-15	10-15			0-5	0-8
0.075	<5	<5	<5	<5		0-3

Table 22.6: Physical Requirement for Materials for Granular Sub-base

Physical properties	Test method	Requirement for Class I & II	Requirement for Class III , IV and maintenance work
Aggregate Impact Value (AIV)	IS 2386-4 or IS 5640	Maximum 40	Maximum 45
Liquid Limit	IS 2720-5	maximum 25	maximum 25
Plasticity Index	IS 2720-5	Maximum 6	Maximum 6
CBR at 95 % dry density (at IS 2720- part8)	IS 2720-5	Minimum 30 unless specified in the Contract	Minimum 25 unless specified in the Contract

D. Compaction Trials

Before commencing construction and from time to time as may be considered necessary by the Engineer, the Contractor shall carry out compaction trials in the presence of Engineer on each main types of materials to be compacted in the Works. He shall carry out all necessary laboratory and field testing and supply the Engineer with the copies of the results of all tests.

Following completion of the compaction trials, the Contractor shall submit to the Engineer, for his approval, proposals for the compaction of each main type of material. The Contractor's Proposals shall include reference to the type of equipment, the operating weights and tyre pressures and the method of adjusting moisture content.

If, in the opinion of the Engineer, the results of the compaction trials indicate that the Contractor's proposed plant and methods shall achieve the densities specified, the Engineer shall approve the same. Otherwise, the Contractor shall submit in writing proposals for modifying the plant and/or methods and shall compact further trials in accordance with these modified proposals until the Engineer approves the Contractor's proposals.

E. Laying and Compacting

Immediately before laying the subbase material, the underlying layer shall be checked by the Contractor for any damage or deficiencies, which shall be made good as instructed by the Engineer.

The material shall be deposited in such quantity and spread in a uniform layer across the full width required, so that the final compacted thickness is nowhere less than shown on the Drawing or instructed by the Engineer. Every reasonable effort shall be made to prevent segregation during mixing, dumping, spreading, trimming and compacting operations.

After spreading, Compaction shall be done by an 8-10 MT road roller. The compacted thickness of any layer laid, processed and compacted at one time shall not exceed 150 mm and when a greater compacted thickness is required, the material shall be laid and processed in two or more layers. The minimum layer thickness shall be 100 mm.

The material shall be down to the grading specified in Sub-clause 2208(C). Any oversize material which cannot be broken down to the required size shall be removed and disposed off.

The material shall be scarified and the moisture content adjusted by either uniformly mixing with water or drying out the material such that the moisture content during compaction is between 95% and 100% of the Optimum Moisture Content (IS: 2720 Part 8). It shall be graded and trimmed to final line and level. Light compaction may be applied before the final trim is carried out, but once 25% of the compactive effort has been applied no further trimming or correction of surface irregularities shall be allowed.

All rolling shall be longitudinal and shall commence at the outer edges of the pavement and progress towards the center, except that on super elevated curves, rolling shall progress from the lower to the higher edge. Where laying is carried out in lanes care must be taken to prevent water entrapment.

The final trim shall be in cut and the Contractor shall ensure that material from the trim is neither deposited in low areas nor spread across the section but graded clear of the works. Following the final trim the material shall be compacted to a dry density of at least 95% of MDD (IS: 2720 Part 8). During the grading, trimming and compaction of the material the Contractor shall ensure that the surface and/or the material does not dry out. If so, the Contractor need to apply fog sprays of water or other approved means sufficient to maintain the surface and/or material within the specified limits of moisture content.

On completion of compaction, the surface shall be well closed, free from movement under compaction plant and free from compaction planes, ridges, and cracks, lose or segregated material. If the surface fails to meet the specified requirements, the Contractor shall take the action set out in the appropriate part of Section 2202 or such other action as directed by the Engineer.

F. Setting out and Tolerances

The layer shall be set out and constructed to the appropriate tolerance specified in Clause 2202.

G. Drainage of Subgrade and Subbase

The subgrade and subbase shall be kept continuously drained and any damage caused by water accumulating on or running off the surface shall be made good at the Contractor's expense.

Water accumulated on any part of the subgrade or subbase, shall be removed and disposed off. Any material which becomes saturated, or cannot then be compacted to the required density, shall be replaced as specified at Contractor's own expense.

H. Requirement for Granular subbase

The minimum testing frequency for the purpose of process control shall be as per Table 8.8.

Routine inspection and testing shall be carried out by the Engineer to test the quality of materials and workmanship for compliance with the requirements of this Section.

Any materials or workmanship that do not comply with the specified requirements shall be replaced with materials and/or workmanship complying with the specified requirements or be replaced to comply with the specified requirements.

I. Measurement

Subbase construction shall be measured in square meter by measuring the average width and length of the road section at intervals of 20 meters or as directed by the Engineer. Rolling/Compaction works, if included as separate item shall be measured in cubic meter.

J. Payment

The subbase construction works and separate rolling/compaction works shall be paid at their respective contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115.

2209 WATER BOUND MACADAM BASE AND SUB-BASE

A. Scope

This work shall consist of clean, crushed aggregates mechanically interlocked by rolling and bonded together with screening binding material (Clay, Sand, Stone dust, etc) and water laid on a properly prepared subgrade/subbase/base or existing pavement, as the case may be and finished in accordance with the requirements of this specification and in close conformity with the lines, grades, cross Sections and thickness as per approved plans or as directed by the Engineer. Grading to be adopted for a project shall

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be as specified in the Contract.

B. Sources of Materials

The Contractor shall be responsible for locating and developing suitable sources of material for water bound macadam. Such sources shall be termed quarries or borrows. The opening up of quarries/borrows and the construction and maintenance of access roads shall be carried out in accordance with specification.

C. Material Requirements

(i) Coarse Aggregates

Coarse aggregates shall be either crushed or broken stone, crushed slag. The aggregates shall conform to the physical requirements set forth in Table 22.7.

Table 22.7: Physical Requirements of Coarse Aggregates for Water Bound Macadam for Subbase / Base course

S.N.	Test	Requirements (Base)	Requirements Sub base	Test method
1	Loss Angeles Abrasion Value (LAA)	40 max	45	IS: 2386 -4
	Or Aggregate Impact Value (AIV)	30 max	40 max	IS: 2386-4 or IS: 5640**
2	Combined Flakiness and Elongation index ***	35 max	35 max	IS: 2386 -1

Note:

*1. **Aggregates which get softened in presence of water shall be tested for Impact value under wet condition as per IS: 5640*

*2. ***The requirement of flakiness index and elongation index shall be enforced only in the case of crushed broken stone and crushed slag.*

The crushed or broken stone shall be hard, durable and free from excess flat, elongated, soft and disintegrated, dirt and other deleterious material. After processing, placing and compaction in the place the grading of the material shall be a smooth curve within and approximately parallel to one of the envelopes defined in Table 22.8.

Table 22.8: Grading Envelope of Coarse Aggregates

Sieve Size (mm)	Percentage passing by weight	
	Grading 1 (63-45 mm)	Grading 2 (53-22.4 mm)
75.0	100	-
63.0	90-100	100
53.0	25-75	95-100
45.0	0-15	65-90
22.4	0-5	0-10
11.2	-	0-5

(ii) Screening

Screening to fill voids in the coarse aggregate shall generally consist of the same material as of the coarse aggregate. However, where permitted predominantly non- plastic material like crushed rock fines or natural angular pit sand may be used for this purpose.

Screening shall conform to the grading set forth in Table 22.9.

Table 22.9: Grading Requirements for Screenings

Sieve Size (mm)	Percent passing by Weight	
	Grading 1 (13.2 mm)	Grading 2 (11.2mm)
13.2	100	
11.2	95-100	100
9.50		80-100
5.6	15-35	50-70
0.18	0-10	5-25

(iii) Binding material

Binding material to be used for water bound macadam as a filter material meant for preventing raveling, shall comprise of a suitable material approved by the Engineer having a Plasticity Index (PI) value of less than 6 as determined in accordance with IS : 2720 (Part-5). The quantity of binding material where it is to be used, will depend on the type of screenings. Generally, the quantity required for 75 mm compacted thickness of water bound macadam will be 0.06-0.09 $m^3/10m^2$ (The quantities should be taken as a guide only, for estimation of quantities for construction etc., Application of binding materials may not be necessary when the screenings used are of crushable type such as moorum or gravel).

D. Compaction Trials

The Contractor shall carry out trials in accordance with Sub-clause 2208(D).

E. Construction Operations

(i) Preparation of Base

The surface of the sub-grade/sub-base/base to receive the water bound macadam course shall be prepared to the specified lines and cross fall and made free of dust and other extraneous material. Any ruts or soft yielding places shall be corrected in an approved manner and rolled if necessary, by sprinkling water until firm surface in obtained.

As far as possible, laying water bound macadam course over an existing thick, bituminous layer may be avoided since it shall cause problems of internal drainage of the pavement at the interface of two courses. It is desirable to completely pick out the existing thin bituminous wearing course where water bound macadam is proposed to be laid over it. However, in exceptional cases, where the intensity of rain is low and the interface drainage facility is efficient, water bound macadam can be laid over the existing thin bituminous surface by cutting 50 mm x 50 mm furrows at an angle of 45 degrees to the center line of the pavement at one-meter intervals in the existing road. The directions and depth of furrows shall be such that they provide adequate bondage and also serve to drain water to the existing granular base course beneath the existing thin bituminous surface.

(ii) Inverted Choke

If water bound macadam is to be directly over the sub-grade, without any other intervening pavement course, a 25 mm thick screenings or coarse sand shall be spread on the prepared subgrade before application of the coarse aggregates is taken up.

(iii) Spreading Coarse Aggregates

The coarse aggregates shall be spread uniformly and evenly upon the prepared subgrade/subbase/base to proper profile by using templates placed across the road about 6 m apart, in such quantities that the thickness of each compacted layer is not more than twice the maximum size of the aggregate. Whenever possible, approved mechanical devices shall be used spread the aggregates uniformly so as to minimize the need for manual rectification afterwards. Aggregates placed at locations which are inaccessible to the spreading equipment, may be spread in one or more layers by any approved means so as to achieve the specified results.

The spreading shall be done from stockpiles along the side of the roadway or directly from vehicles. In no

case the aggregates shall be dumped in heaps directly on the surface prepared to receive the aggregate nor shall hauling over uncompact or partially compacted base be permitted. No segregation of coarse or fine aggregates shall be allowed and the coarse aggregate as spread shall be of uniform gradation with no pockets of fine material.

The surface of the aggregates spread shall be carefully checked with templates and all high or low spots shall be made to the level by removing or adding aggregate as required. The surface shall be checked frequently with a straight edge while spreading and rolling so as to ensure a finished surface as per approved plan.

(iv) Rolling

Immediately following the spreading of the coarse aggregate, rolling shall be started with three wheeled power rollers of 8-to-10-ton capacity or tandem or vibratory rollers of approved type. The type of roller to be used shall be as specified in the contract and approved by the Engineer based on trial run.

Except on super elevated portions where the rolling shall proceed from inner edge to the outer rolling shall begin from the edges gradually progressing towards the center. First the edge/edges shall be compacted with roller running forward and backward. The roller shall then move inwards parallel to the centerline of the road, in successive passes uniformly lapping preceding tracks by at least one-half width of wheel of the roller.

Rolling shall be discontinued when the aggregates are partially compacted with sufficient void space in them to permit application of screenings. During rolling, slight sprinkling of water may be done, if necessary. Rolling shall not be done when the subgrade is soft or yielding or when it causes a wave-like motion in the subgrade or subbase course.

The rolled surface shall be checked transversely and longitudinally, with templates and any irregularities corrected by loosening the surface, adding or removing necessary amount of aggregates and re-rolling until the entire surface conforms to desired cross fall and grade. In no case shall the use of screenings be permitted to make up depressions.

Material which has been crushed excessively during compaction or have become segregated shall be replaced with aggregates of the same or better quality.

(v) Application of Screenings

After the coarse aggregate has been rolled as above screenings shall be applied gradually over the surface to completely fill the interstices. These shall not be damp or wet at the time of application. Dry rolling shall be done while the screenings are being spread so that vibrations of the roller cause them to settle into the voids of the coarse aggregate. The screenings shall not be dumped in piles but be spread uniformly in successive thin layers either by the spreading motions of hand shovels or by mechanical spreaders, or directly from tipper with suitable grit spreading arrangement. Tipper operating for spreading the screening shall be so driven as not to disturb the coarse aggregate.

The screenings shall be applied at a slow and uniform rate (in three or more applications) so as to ensure filling of all voids. This shall be accompanied by dry rolling and brooming with mechanical brooms, hand-brooms or both. In no case shall the screenings be applied as fast and thick as to form cakes of ridges on the surface in such a manner as would prevent filling of voids or prevent the direct bearing of the roller on the coarse aggregate. These operations shall continue until no more screening can be forced into the voids of the coarse aggregate.

The spreading, rolling, and brooming of screening shall be carried out in only such lengths of the road which could be completed within one day's operation.

(vi) Sprinkling of Water and Grouting

After the screening have been applied, the surface shall be copiously sprinkled with water, swept and rolled. Hand brooms shall be used to sweep the wet screenings into voids and to distribute them evenly. The sprinkling, sweeping and rolling operation shall be continued, with additional screenings applied as

necessary until the coarse aggregate has been thoroughly keyed, well-bonded and firmly set in its full depth and a grout has been formed of screenings. Care shall be taken to see that the base or subgrade does not get damaged due to the addition of excessive quantities of water during construction.

In case of lime treated soil sub-base, construction of water bound macadam on top of it shall be taken up after curing of sub as directed by the Engineer.

(vii) Application of binding material:

After the application of screenings in accordance with above (v) and (vi), the binding material where it is required to be used shall be applied as per Clause 2209(C) successively in two or more thin layers at a slow and uniform rate. After each application, the surface shall be copiously sprinkled with water, the resulting slurry swept in with hand brooms, or mechanical brooms to fill the voids properly, and rolled during which water shall be applied to the wheels of the rollers if necessary to wash down the binding material sticking to them. These operations shall continue until the resulting slurry after filling of voids, forms a wave ahead of the wheels of the moving roller.

(viii) Setting and Drying

After the final compaction of water bound macadam course the pavement shall be allowed to dry overnight. Next morning hungry spots shall be filled with screenings or binding material as directed, lightly sprinkled with water if necessary and rolled. No traffic shall be allowed on the road until the macadam has set. The Engineer shall have the discretion to stop hauling traffic from using the completed water bound macadam course, if in his opinion it would cause excessive damage to the surface.

The compacted water bound macadam course shall be allowed to completely dry and set before the next pavement course is laid over it.

F. Setting out and Tolerances

Water bound macadam base and subbase shall be set out and constructed within the tolerances given in Clause 2202.

G. Quality control

The minimum testing frequency for process control shall be as per Table 8.8 and construction tolerance shall be as specified in Clause 2202. Routine inspection and testing shall be carried out by the Engineer to test the quality of materials and workmanship for compliance with the requirements of this Section.

Any materials or workmanship that do not comply with the specified requirements shall be replaced by materials and workmanship complying with the specified requirements or be repaired so that after being repaired it shall comply with the specified requirements.

H. Reconstruction of defective macadam:

The finished surface of water bound macadam shall conform to the tolerance of surface regularity as prescribed in Clause 2202. However, where the surface irregularity of the course exceeds the tolerances or where the course is otherwise defective due to subgrade soil mixing with the aggregates, the course to its full thickness shall be scarified over the affected area, reshaped with added material or removed and replaced with fresh material as applicable and re-compacted. In no case shall depressions be filled up with screening or binding material.

I. Measurement

Water bound macadam subbase/base shall be measured in square meter by measuring the average width and length of the road section at intervals of 20 meters or as directed by the Engineer. Rolling/Compaction works, if included as separate item shall be measured in cubic meter.

J. Payment

Water bound macadam subbase/base and separate rolling/compaction works shall be paid at their respective contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115.

2210 ROADSIDE DRAINS/DITCH

A. General

Roadside drain shall be constructed as per drawing for safe passage of water for the protection of road surface. Drain shall be earthen (unlined), lined with boulder masonry or lined with dry boulder as specified. Drain shall be constructed by boulder masonry in cement sand mortar of different cement sand ratio or by dry masonry of different shapes (Rectangular, V shaped, etc.) or earthen (unlined) in various soil textures as described in the contract or on the drawing. The thickness of roadside drain shall be as specified and approved by the Engineer.

B. Material

Materials for the construction of roadside drain shall be cement, sand, water and boulder as required and shall be of appreciable quality as mentioned in the respective sections of this specification.

C. Depth of Roadside Drains

The depth of roadside drain shall be as specified in the drawing. The difference between road level measured at the centre line of the road and that of the bottom of the side drain measured perpendicular to the centre line of the road shall not deviate from the specified in the drawing by ± 25 mm.

D. Measurement and Payment

Dry boulder masonry and boulder masonry in cement concrete mortar drains shall be measured in cubic metres of actual masonry works performed. Earthen unlined drains of specified width shall be measured in running meter of actual earthen excavation performed.

Payment of the works shall be made at their respective contract unit rate.

2211 GENERAL REQUIREMENTS FOR BITUMINOUS PAVEMENT LAYERS

A. Scope

This Clause comprises general requirements for bituminous pavement courses. The use of machinery and equipment mentioned in various Clauses of these Specifications is mandatory.

B. Bituminous Binder

All bituminous binders shall comply with the relevant requirements set out in specification. The choice of binder shall be stipulated in the Contract or by the Engineer. Where viscosity grades of bitumen are specified, it shall conform to the requirements of IS: 73. Where modified bitumen is specified, it shall conform to the requirements of IRC: SP: 53 and IS: 15462; and the following provision of this Specification shall apply.

(i) Modified bitumen from refinery sources or blended at approved central plant or at site using appropriate industrial process and plant with high shear mill, and testing facilities to achieve stable and homogenous mix shall be used. The use of high shear mixer or any other device capable of producing a homogeneous blend is essential when the modifier is in powder form.

(ii) Transportation tanks and storage tanks shall be insulated and equipped with effective heating system and circulation/ agitating device to maintain the specified temperature, homogeneity and viscosity of the bitumen during transit and storage.

(iii) Separation, difference in softening point (R&B), shall not be more than 3°C for any type of specified modified bitumen when tested as per Annex B of IS: 15462.

Selection criteria for viscosity grade bitumen, based on highest and lowest daily mean temperatures at a particular site, Table 22.10.

Selection criteria for modified bitumen shall be in accordance with IRC- Sp. 53, / Table 22.11.

Table 22.10: Selection Criteria for Viscosity-Graded (VG) Paving Bitumen Based on Climatic Conditions

Lowest Daily Mean Air Temperature, °C	Highest Daily Mean Air Temperature, °C		
	Less than 20°C	20 to 30°C	More than 30°C
More than -10°C	VG-10	VG-20	VG-30
-10°C or lower	VG-10	VG-10	VG-20

Table 22.11 Selection criteria for Modified bitumen. Based on Climatic Conditions

S. No	Highest Mean Air Temperature	<20° C	20° C – 35° C	Above 35° C	Method of Test IS No (6)
	Lowest Mean Air Temp			>-10°C	
(1)	Characteristics (2)	Specified value for Bitumen (3)	(4)	(5)	
i	Penetration at 25° C 0.1 mm, 100g, 5S	60 to 120	50 to 80	30 to 50	1203
ii	Softening point, (R& B) °C Min	50	55	60*	1205
iii	FRAASS** Braking Point, °C Max	-20	-16	-12	9381
iv	Flash point COC °C Min	220	220	220	1209
v	Elastic Recovery of half thread in ductilometer at 15° C , percent Min	50	60	60	IRC – SP 53 annexure- 2
vi	Complex modulus (G*/sinδ) as minimum 1.0 Kpa at 10 rad/S at a temperature ° C	58	70	76	IRC – SP 53 annexure- 1
vii	Separation, difference in softening point (R & B) °C Max	3	3	3	IRC – SP 53 annexure- 3
viii	Viscosity at 150 ° C Poise	1-3	3-6	5-9	1206 (part 2)
ix	Thin film oven test on residue				
a	Loss in mass, percent, Max	1	1	1	9382
b	Increase in softening point	7	6	5	1205
c	Reduction in penetration of residue, at 25°C, percent, Max	35	25	35	1203
d	Elastic recovery of half thread in ductilometer at 25° C or	35	50	50	IRC – SP 53 annexure- 4
	Complex modulus (G*/sinδ) as minimum 2.2 Kpa at 10 rad/S at a temperature ° C	58	70	76	IRC – SP 53 annexure- 1

- Where Max Temperature exceeds 40°C, softening point should be at 65°C

** Fraas breaking point requirement will be applicable for area of subzero Temperatures.

Choice/ selection criteria of cold mix treatment for different Climate/ Traffic conditions shall be in accordance with IRC- Sp. 100 / Table 22.12.

Table 22.12: Choice/ selection criteria of cold mix treatment for different Climate/ Traffic conditions

Type of Treatment	Traffic (CVPD)	Climate		Choice of Emulsion
		Temperature	Rainfall	
Prime Coat	No Limit	No Limit	No Limit	SS-1
Tack coat	No Limit	No Limit	No Limit	RS-1
Seal Coat	<1500	No Limit	No Limit	SS-2
Sand Seal	<1500	No Limit	No Limit	SS-2
Cap Seal	<3000	No Limit	No Limit	RS-2/ SS-2, / Modified
Chip Seal	<1500	Avoid in Cold Climate	No Limit	Rs-2/ Modified
Slurry Seal	<1500	No Limit	No Limit	SS-2
Micro surfacing	No Limit	No Limit	No Limit	Modified
Open Graded Premix Carpet (OGPC)	<1500	Moderate & cold climate (maximum air temperature 40° C)	Medium	MS/ SS-2, / Tailor made
Mix Seal Surfacing (MSS)	<1500	Moderate & cold climate (less than 40° C)	Low	MS/ SS-2, / Tailor made
Bituminous Mix (BM)	<1500	Moderate & cold climate (maximum air temperature 40° C)	Low	MS/ SS-2, / Tailor made
Semi Dense Bituminous Concrete (SDBC)	<3000	Moderate & cold climate (maximum air temperature 40° C)	Low	SS-2, / Tailor made
Half Warm Mix (DBM, SDBC, BC)	<4500	Moderate & cold climate (maximum air temperature 40° C)	No Limit	SS-2, / Tailor made
Cold Recycling	No Limit	Moderate & cold climate	No Limit	SS-2, / Tailor made
Patching	No Limit	No Limit	No Limit	MS/ SS-2 / Tailor made

Recommended uses for different types of Emulsion on Climatic Conditions are as follows:

Type	Recommended Use
RS 1	A quick setting Emulsion used for Tack coat
RS 2	A quick setting Emulsion used for surface treatment, Surface dressing Penetration Macadam
MS	A medium setting emulsion used for plant or road mixes with coarse aggregate for premix carpet
SS - 1	A slow setting emulsion used for priming
SS - 2	A slow setting emulsion used for plant mixes with graded fine aggregates in SDBC, MSS, BM, DBM and BC. This emulsion is used for slurry seal treatment and tack coat
Modified	Modified Emulsion is used for micro surfacing

C. Storage and Handling of Bituminous Binder

When carried in bulk containers, of binder temperature during and at the time of storage shall be kept in a manner acceptable to the Engineer. During storage the temperature of the bituminous binder shall be kept as low as possible, consistent with reasonable pump ability. Any bituminous binder not conforming to the requirements of Sub-clause 2211(D) shall be rejected by the Engineer as unsuitable for use.

When bitumen emulsion is stored on site in large container, then the conditions of storing shall comply with the manufacturer's instructions and/or as per IS: 3117/8887.

Where bitumen emulsions are stored on site in drums, the drums shall be regularly "rolled" to ensure mixing of the contents. Prior to using, all bituminous emulsion drums shall be "rolled" just before opening and use. Emulsions shall be protected against frost and temperatures below 3° C.

The bitumen storage area and heating station shall be cleared of vegetation, kept neat and tidy. The drums shall be stacked on their sides in small quantities with gaps between each stack to reduce fire risk.

Bitumen distributors and boilers shall be kept clean at all times. When changing the grade of bitumen and at the end of each day's work, all boilers and distributors shall be thoroughly cleaned out with a solvent. The flushing's from boilers and distributors shall not be poured anywhere indiscriminately but shall be led by drainage channels to disposal pits. Care shall be taken that flushing's do not find their way into storm water ditches or streams. All boilers, pre-heating pits, tools and plant shall be kept scrupulously clean.

When filling the bitumen distributor from the boilers or bulk containers, the bitumen shall be passed through a filter of fine wire mesh having opening of not more than 0.6 mm.

On completion of the works, the disposal pit and drainage channels shall be filled in and top soiled. The site shall be left clean and tidy.

D. Heating of Bituminous Binder

The bituminous binder shall be heated in boilers or bulk storage containers, equipped with adequate pumps and accurate thermometers. No bitumen shall be heated in a boiler when the thermometer is broken, inaccurate or not equipped with it.

Pre-mixed bituminous materials shall be prepared in a hot mix plant of adequate capacity and capable of yielding a mix of proper and uniform quality with thoroughly coated aggregates. Appropriate mixing temperatures are given in Table 22.14 of these Specifications. The difference in temperature between the binder and aggregate shall at no time exceed 14°C. In order to ensure uniform quality of the mix and better coating of aggregates, the hot mix plant shall be calibrated from time to time. The essential features of the hot mix plants are given in Annex A. of IRC: 27.

The minimum pumping temperatures, the range of spraying temperatures and the maximum heating temperatures of cut-backs, Viscosity grade bitumen's and emulsions are given in Table 22.13 below.

Table 22.13: Temperatures Ranges for Heating and Spraying Binders

Binder	Minimum Pumping	Temperatures (°C) Spraying *		Maximum Heating
		Slot- jets	Atomizing jets	
Cut-back RC 800	60	110-115	-	120
Cut-back RC 3000	80	125-135	-	135
Cut-back MC 30	10	35-45	50-60	65
Cut-back MC 70	25	55-65	70-85	85
Cut-back MC 800	60	100-115	120-135	135
Cut-back MC 3000	80	125-135	135-150	150
Paving Bitumen	105	155-165	160-170	170
Emulsion ** Cationic	-	-	-	95
Emulsion ** Anionic	-	-	-	95

** These spraying temperatures are for guidance only, since the optimum spraying temperature depends on the temperature/viscosity relationship of the bitumen.*

** The minimum pumping and spraying temperatures for Cationic / Anionic Emulsion shall be in accordance with the manufacturer's recommendations.*

Recommended Mixing, Laying and Rolling Temperatures for Bituminous Mixes (Degree Celsius) is specified in Table 22.14. In case of modified bitumen, the temperature of mixing and compaction shall be higher than the mix with conventional binder. The exact temperature depends upon the type and amount of modifier used and shall be adopted as per the recommendation of the manufacturer.

Table 22.14: Mixing, Laying and Rolling Temperature for Bituminous mix

Bitumen Viscosity Grade	Bitumen Temperature	Aggregate Temperature	Mixed Material Temperature	Laying Temperature	*Rolling Temperature
VG-40	160-170	160-175	160-170	150 Min	100 Min
VG-30	150-165	150-170	150-165	140 Min	90 Min
VG-20	145-165	145-170	145-165	135 Min	85 Min
VG-10	140-160	140-165	140-160	130 Min	80 Min

For slot-jets the viscosity for spraying shall be 70 to 100 centistokes and for atomizing jets 35 to 60 centistokes.

No pavement bitumen, cut-back bitumen, or emulsion shall be heated above the maximum temperature given in the Table 22.13. Any overheated bitumen or emulsion shall be removed from the site and disposed of by the Contractor.

The rates of application of binder specified or instructed by the Engineer refer to volumes of binder shall be corrected to 15.6°C using Standard Petroleum Measurement as specified in Annex 2200-1.

E. Weather Limitations

In case of following situation, Laying shall be suspended:

(i) In presence of standing water on the surface;

(ii) When rain is imminent, and during rains, fog or dust storm;

(iii) When the base/binder course is damp;

(iv) When the air temperature on the surface on which it is to be laid is less than 10°C for mixes with conventional bitumen and is less than 15°C for mixes with modified bitumen;

(v) When the wind speed at any temperature exceeds the 40 km per hour at 2 m height. Bituminous material, except for bitumen emulsions and certain types of prime coat if instructed by the Engineer, shall not be applied on a damp surface.

F. Cutting Back of Bitumen

The maximum amounts of paraffin as given in Table 22.15 may be added with the permission of the Engineer to the basic grade of bitumen upon the road surface temperature at the time of spraying. Lesser amounts than those indicated may be used, if the site conditions allow the development of sufficient adhesion between binder, aggregate and existing surface. Diesel or kerosene shall be used for cutting back of bitumen as per the direction of the Engineer.

Table 22.15: Maximum Addition of Paraffin

Range of Road Surface Temperature ° C	Maximum Addition of Paraffin by Volume %	Range (approximate) of Corresponding Ambient Air Temperature ° C
22-29	7	10-16
22-36	5	16-21
39-43	3	21-26
43-50	1	26-31
above 50	NIL	above 31

The temperature of bitumen, when paraffin is introduced, shall not be higher than 120° C. The paraffin shall

be sucked from 200-liter drums in measured quantities through the bitumen pump and circulated with the bitumen for a minimum of 45 minutes. During this process all burners shall be shut off and no open flames allowed near the distributor.

Cutback bitumen may be produced by the addition of volatile diluents (cutter) in accordance with Transport Research Road Laboratory TRRL Research Report RR 140 "Preparation of Cutback Bitumen"

Adhesion Agent /Anti-Stripping Agent

Where the proposed aggregate fails to pass the stripping test then an approved anti- stripping agent may be added to the binder in accordance with the manufacturer's instructions. The effectiveness of the proposed anti-stripping agent must be demonstrated by the Contractor, before approval by the Engineer

The Engineer may prescribe some additional periodic test such as “underwater coating test” stripping value for passive adhesive, Thermal stability, or solubility in high-speed diesel” to confirm that the adhesive agent being used is as claimed by the manufacture.

The anti-stripping agent shall meet the requirements as given in Table 22.16;

Table 22.16 Specification for Anti-stripping Agent

Description	Test method	Requirements
Appearance	Visual	Dark Brown Liquid
Specific Gravity at 27^0C	IS 1448	0.85 ±0.1
Pour point	IS 1448	Max 42
Flash point	IS 1448	>150^0C
Moisture content	IS 1448	Max 1.0 %
Solubility in Diesel Oil in the Ratio 2:98 at 50^0 C	IS 6241	Min 95%
Stripping Value with Bitumen Containing 1 % Agent 40^0 C for 24 Hours	IS 6241	No Stripping
Underwater coating test	IS 6241	Min 95%
Thermal stability at 163^0C	IS 6241	Stable

Where required the adhesion agent shall be of an approved type and shall be used in accordance with the manufacturer’s instructions and as instructed by the Engineer.

G. Requirement of Bituminous Mix

(i) Asphalt Plant

Bituminous materials shall be mixed in a plant complying with IS: 3066 and shall be located on nearby location of the site unless otherwise agreed by the Engineer. It shall be equipped with at least three bins for the storage of heated aggregates and a separate bin for filler. All bins shall be covered to prevent the ingress of moisture.

The plant may be either batch-mix type or the continuous-mix type and shall be capable or regulating the composition of the mixture.

The bitumen tank shall be capable of maintaining its contents at the specified temperature within a tolerance of plus or minus 5° C and shall be equipped with a thermostat to prevent the temperature rising above 180^oC and a fixed thermometer easily read from outside the tank. Any bitumen which has been heated above 180^oC or has suffered carbonization from prolonged heating shall be removed from the plant and disposed off.

(ii) Mix design

The bitumen content required shall be determined following the Marshal mix design procedures contained in Asphalt institute manual MS-2.

At least two months prior to commencing work using a bituminous mix, the Contractor shall be having

demonstrated that he can produce aggregates meeting the grading requirements of the Specification, submit samples of each constituent of the mix to the Engineer.

The maximum size of the aggregate for wearing course shall equal to or less than the thickness of wearing course divided by 2.5 and that for binder course shall equal to or less than thickness or binder course divided by 2.

The Contractor shall then carry out laboratory tests in order to propose the proportions of each consistent of the initial mix or mixes to be used for site trials to be carried out in accordance with these specifications.

The Engineer shall conclude form the site trials that the mix proportions or aggregate grading are to be changed, the Contractor shall submit further samples of the constituents, carry out further laboratory and site trials as directed by the Engineer.

(iii) Mixing of Aggregate and Bitumen

The bitumen shall be heated so that it can be distributed uniformly. Care shall be taken not to overheat it. The temperature shall never exceed 170° C for paving bitumen.

The aggregate shall be dried and heated so that they are mixed at the following temperatures unless otherwise specified in respective Clause.

Proposed Bitumen	Temperature in ^{o}C
VG 10	125-160
VG 20 or VG 30	130- 170

The dried aggregates shall be combined in the mixer in the amount of each fraction of the agreed mix and the bitumen shall then be introduced into the mixer in the amount specified. The materials shall then be mixed until a complete and uniform coating of the aggregate is obtained.

The mixing time shall be the shortest required to obtain a uniform mix and thorough coating. The wet mixing time shall be determined by the Contractor and agreed by the Engineer for each plant and for each type of aggregate used. It shall normally not exceed 60 seconds.

(iv) Transportation of the Mixture

The bituminous mix shall be kept free of contamination and segregation during transportation. Each load shall be covered with canvas or similar covering to protect it from dust and adverse effect of the weather.

(v) Laying of the Mixture

Immediately after the surface has been prepared and approved, the mixture shall be spread to line and level by the laying plant without segregation and dragging.

The mixture shall be place in widths of one traffic lane at a time, unless otherwise agreed by the Engineer. The compacted thickness of nay layer shall be at least 2.5 times the maximum size of the aggregate for wearing course and at least 2 times the maximum size of the aggregate for binder course.

Only on area where irregularities or unavoidable obstacles make the use of mechanical laying impracticable, the mixture may be spread and compacted by hand.

(vi) Compaction

Immediately after the bituminous mixture has been spread, it shall be thoroughly and uniformly compacted by rolling.

The layer shall be rolled when the mixture is in such a condition that rolling does not cause undue displacement or shoving.

The number, weight and type of rollers furnished shall be sufficient to obtain required compaction while the mixture is in a workable condition. The sequence of rolling operations shall be as agreed with the Engineer.

Initial rolling with a steel tandem of three-wheeled roller shall follow the laying plant as closely as possible. The rollers shall be operated with the drive roll nearest the laying plant, at a slow and uniform speed (not

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exceeding 5 km/h).

Rolling shall normally commence from the outer edge and proceed longitudinally parallel to the centerline, each trip overlapping one half of the roller width. On super elevated curves, rolling shall begin at the low side and progress to the high side. Where laying is carried out in lanes care must be taken to prevent water entrapment.

Intermediate rolling with a pneumatic tyre or vibratory roller shall follow immediately. Final rolling with a steel wheeled roller shall be used to eliminate marks from previous rolling.

To prevent adhesion of the mixture to the rollers, the wheels shall be kept lightly moistened with water. In areas too small for the roller, a vibrating rate plate compactor or a hand tamper shall be used to achieve the specified compaction.

(vii) Finishing, Joint and Edges

Any mixture that becomes loose and broken, mixed with dirt or foreign matter or is in any way defective, shall be replaced with fresh hot mixture, which shall be compacted to conform to the surrounding area.

Spreading of the mixture shall be as continuous as possible. Transverse joints shall be formed by cutting neatly in a straight line across the previous run to expose the full depth of the course. The vertical face so formed shall be painted lightly with hot VG10 or similar grade bitumen just before the additional mixture is placed against it.

Longitudinal joints shall be rolled directly behind the paving operation. The first lane shall be placed true to line and level an approximately vertical face. The mixture placed in the abutting lane shall than be tightly crowded against the face of the previously placed lane. The paver shall be positioned to spread material overlapping the joint face by 20 – 30 mm. Before rolling, the excess mixture shall be raked off and discarded.

When the abutting lane is not placed in the same day, or the joint is destroyed by traffic, the edge of the lane shall be cut back as necessary, trimmed to line and painted lightly with hot VG 10 or similar grade bitumen just before the abutting lane is placed.

Any fresh mixture spread accidentally on the existing work at a joint shall be carefully removed by brooming it back on to un-compacted work, so as to avoid formation of irregularities at the joint. The finish at joints shall comply with the surface requirements and shall present the same uniformity of finish, texture and density as other sections of the work.

The edges of the course shall be rolled concurrently with or immediately after the longitudinal joint. In rolling the edges, roller wheels shall extend 50 to 100 mm beyond the edge.

(viii) Sampling and testing of Bituminous mixtures

The test and their minimum frequencies for the different types of bituminous work shall be as given in Table 8.8. The Engineer may direct additional testing as required to fulfil the requirement as specified in corresponding Clause.

The acceptance criteria for tests on density shall subject to the condition that the mean value is not less than the specified value plus:

$$1.65 - \frac{1.65}{\text{Sqrt (No. of samples)}} \times \text{standard deviations}$$

Where the Contract specifies the surface roughness requirements, in terms of Bump integrator value, the surface roughness value shall be measured by a calibrated Bump integrator as per the procedure described in IRC: SP: 16. The measurements shall be taken at centre line of each lane for a minimum completed length of one Km.

During mixing and laying of bituminous mixtures, control tests on the constituents and on the mixed material shall be carried out in accordance with relevant section and relevant Clauses of Section 2211.

If the results of any tests show that any of the constituent materials fail to comply with this Specification, the Contractor shall carry out whatever changes may be necessary to the materials and/or to the source of supply to ensure compliance.

If the results of more than one test in ten on the mixed material show that the material fails to comply with this Specification, laying shall forthwith cease until the reason for the failure has been found and corrected. The Contractor shall replace any faulty material laid with material complying with this Specification all at his expense.

(ix) Tolerance

Surfacing and base shall be constructed within the geometric tolerance specified in Clause 2202.

The Contractor shall maintain the composition of the mixture as determined from the laboratory and site trials with the following tolerances, per single test: -

(a) Bitumen: ± 0.3% of total weight of bitumen in total mix

(b) Aggregates

(i)	Passing through 10 mm sieve and larger sieves	±6% of	Total weight of aggregate including mineral filler
(ii)	Passing through 10 mm sieve and retained on 1mm sieve	±4% of	
(iii)	Passing through 1 mm sieve and retained on 0.075 mm sieve	±3% of	
(iv)	Passing through 0.075 mm sieve	±2% of	

The average amount of bitumen in any length of any layer, calculated as the product of the bitumen contents obtained from single tests and the weight of the mixture represented by each tests, shall not vary beyond the limit of tolerance of the amount specified.

The average amount of bitumen for each day's production calculated form the check weights of mix shall not vary beyond the limits of tolerance of the amount specified.

The final average overall width of the upper surface of a bituminous mix layer measured at six equidistant points over a length of 100 m shall be at least equal to the width specified. At no point shall the distance between the centerline of the road and the edge of the upper surface of a bituminous mix layer be narrower than that specified by more than 13 mm.

H. Safety Precautions

The Contractor shall take every precaution to avoid fire or health hazards. He shall always ensure that:

(a) Bitumen is heated only to the temperature required for the particular application;

(b) Hot bitumen never comes in contact with water;

(c) Suitable protective clothing, foot wears and gloves are used when handling bitumen;

(d) Dust is reduced to the minimum.

Care is required when using rapid-curing cut-back, because of the highly flammable nature of the solvent.

I. Trial Sections

Before commencing execution and from time to time as may be considered necessary by the Engineer the Contractor shall carry out trial sections at location instructed by the Engineer to demonstrate to the Engineer that this his surfacing operation is capable of executing the works in accordance with the Specification.

The Contractor shall allow in his program for conducting site trials and for carrying out the appropriate tests on them. The trial on any pavement layer shall be undertaken at least 21 days ahead of the Contractor proposing to commence the full-scale work on that layer

In case of Bituminous mix Full scale laying and compacting site trials shall be carried out by the Contractor on all asphalt pavement materials proposed for the works using the construction plant and methods

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proposed by the Contractor for construction the works. The trials shall be carried out at a location approved by the Engineer in his presence.

The trials shall be carried out to enable the Contractor to demonstrate the suitability of his mixing and compaction equipment to provide and compact the materials to the specified voids content and confirm that the other specified requirements of he completed asphalt pavement layer can be achieved.

Each trials area shall be at least 100 meters long to the full construction width and depth for the material. It may form part of the Works provided it complies with this Specification. Any areas which do not comply with this Specification shall be removed.

The Contractor shall compact each section of trial over the range of compact effort the Contractor is proposing. The following data shall be recorded for each level of compact effort at each site trial.

(i) The composition and grading of the material including the bitumen content and type and grade of bitumen used.

(ii) The moisture content of aggregate in the asphalt plant hot bins.

(iii) The temperature of bitumen and aggregate immediately prior to entering the mixer, the temperatures of the mix on discharge from the mixer and the temperature of the mix on commencement of laying, on commencement of compaction and on completion of compaction.

(iv) The type, size, mass, width of roll, number of wheels, wheel load, tyre pressures, frequency of vibration and the number of passes of the compaction equipment, as appropriate for the type of roller.

(v) The target voids and other target properties of the mix together with the results of the laboratory tests on the mix.

(vi) The density and voids achieved.

(vii) The compacted thickness of the layer.

(viii) Any other relevant information as directed by the Engineer.

At least eight sets of tests shall be made by the Contractor on each 100 meters of trial for each level of compact effort and provided all eight sets of results over the range of compact effort proposed by the Contractor meet the specified requirements for the material then the site trial shall be deemed successful. The above data recorded in the trial shall become the agreed basis on which the particular material shall be provided and processed to achieve the specified requirements.

During the execution of the works, if the Construction control/process control tests indicate that the requirements for a material are not consistently achieved then work on that layer shall be stopped until the cause is investigated by the Contractor. Such investigation may include further laboratory and/or site trials on the material to determine a revised set of data as described above which when agreed, shall be the basis on which all subsequent material shall be provided and processed to achieve the specified requirements.

Agreement of the Engineer to a set of data recorded in a site trial shall not relieve the Contractor of any responsibility to comply with the requirements of this Specification.

In the course of such trials the Engineer may call upon the Contractor to modify his method of working, to employ other items of equipment and to amend the rates of spread at which various materials are applied.

When the Engineer is satisfied that the Contractor is capable of constructing surfacing that complies with the Specification after trial section or section, the Contractor shall receive permission to commence the work. No variation in the approved procedures shall be made without the Engineer's prior consent in writing.

J. Measurement and Payment

Unless stated otherwise, no separate measurement and payment shall be made for complying with the

requirements of Clause 2211. Related costs of complying with the requirements of Clause 2211 shall be deemed to be included in the related unit rates quoted by the contractor.

2212 PRIME COAT AND TACK COAT

A. Scope and Definitions

This Clause covers the application of a bitumen prime and tack coat to be applied on a prepared pavement layer.

A prime coat means a thin layer of low viscosity bituminous binder applied to an absorbent non-bituminous surface. If the prime coat is to be trafficked, it shall be covered with binding material.

A tack coat means a thin layer of bituminous binder applied to a bituminous surface.

B. Materials

The primer shall be cationic bitumen emulsion SS1 grade conforming to IS: 8887 or medium curing cutback bitumen conforming to IS: 217 or as specified in the Contract. The primer shall comply with specification from a source approved by the Engineer. The grade and the rate of application of cutback to be used shall be instructed by the Engineer on site after field trials. Spray rate may be used as given in Table 22.17 and Table 22.18 as a guideline.

Table 22.17: Quantity of SS1 grade Bitumen Emulsion for Various Types of Granular Surfaces

Type of Surface	Rate of Spray (kg/sq.m)
Low porosity (WMM/WBM)	0.7-1.0
Medium porosity (Mechanically stabilized soil base, lime/ cement stabilized soil and lime cement base)	0.9-1.2
High porosity (Stabilized soil bases/Crusher Run Macadam)	1.2- 1.5

Table 22.18: Type and Quantity of Cutback Bitumen for Various Types of Granular Surface

Type of Surface	Type of Cutback	Rate of Spray (kg/sq.m)
WMM/WBM	MC 30	0.6-0.9
Stabilized soil bases/ Crusher Run Macadam	MC 70	0.9-1.2

For Tack coat, the binder shall be an either Cationic bitumen emulsion (RS 1) complying with IS: 8887 or suitable low viscosity paving bitumen of VG 10 grade conforming to IS: 73. The use of cutback bitumen RC: 70 as per IS: 217 shall be restricted only for sites at sub-zero temperatures or for emergency applications as directed by the Engineer.

No dilution or heating at site of RS 1 bitumen emulsion shall be permitted. Paving bitumen if used for tack coat shall be heated to appropriate temperature in bitumen boilers to achieve viscosity less than 2 poise. The normal range of spraying temperature for a bituminous emulsion shall be 20°C to 70°C and for cutback, 50°C to 80°C. The method of application of tack coat will depend on the type of equipment to be used, size of nozzles, pressure at the spray bar, and speed or forward movement. The Contractor shall demonstrate at a spraying trial, that the equipment and method to be used is capable of producing a uniform spray, within the tolerances specified. Spray rate of Tack coat given in Table 22.19 may be used as guidelines.

Table 22.19: Rate of Application of Tack Coat

Type of Surface	Rate of Spray (kg/sq.m)
Bituminous surfaces	0.40-0.60
Granular surfaces treated with primer	0.50- 0.60
Cement concrete pavement	0.60-0.70

The binding layer, if any shall be crushed rock or river sand having grading within the limits of the table below. The aggregate shall be clean, hard and free from excessive dust. It shall contain no clay, loam or

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other deleterious materials. Grading for sand for Prime coat shall satisfy the requirement specified in Table 22.20

Table 22.20: Grading Envelope for Sand for Prime Coat

Sieve size (mm)	Percentage Passing (by mass)
4.75	100
2.36	80-100
1.18	60-95
0.6	30-80
0.3	20-55
0.075	10-30

C. Preparation of Surface.

The surface to be sprayed shall be thoroughly cleaned by sweeping with mechanical brooms and/or washing or other approved means. All laitance of soil or binder material, loose and foreign material shall be removed.

All loose material shall be swept clear of the layer to expose the full width of the layer upon which prime/tack coat shall be applied. The surface to be sprayed shall be checked for line, camber and level, and the surface corrected, made good as necessary and approved by the Engineer before any bituminous spray is applied. The Engineer's approval, or otherwise, of the surface shall be given immediately prior to the Contractor's intention to start spraying.

Unless otherwise directed by the Engineer, immediately prior to the application of prime coat, the surface of the layer shall be sprayed with water to dampen the surface, but in no case the surface shall be made saturated. If the water is over applied, the surface shall be allowed to dry until dampness is uniform over the entire surface.

In order to bring the surface to be primed to the condition required, water shall be applied in small increments by a distributor. Any water on the surface after spraying shall be allowed to drain away before the prime coat is applied.

No traffic shall be allowed on the prepared surface.

D. Spraying of Prime Coat and Tack Coat

Soon after the surface to be sprayed has been prepared as specified in Sub-clause 2212(C) and approved by the Engineer, the edges of the area shall be marked out with a line of string or wire pegged down at intervals not exceeding 15 m on straights or 7.5 m on curves. The prime or tack coat shall be sprayed on to it at the specified rate. Spraying shall be carried out not later than 12 hours after the surface has been prepared.

The quantity of binder used shall give complete coverage of the surface with a slight trace of run-off in places. Shall the specified rate of spray appear to be incorrect, the Contractor shall immediately stop spraying, inform the Engineer and amend the spray rate as instructed by the Engineer.

The temperature for storage and spraying shall be as given in the Table 22.21.

Table 22.21: Temperature for Storage

Type of Prime	Maximum storage temperature º C	
	Up to 24 hrs.	Over 24 hrs.
Cutback bitumen's		
MC-30	65	40
MC-70	80	50

Bitumen shall be sprayed from a pressure distributor complying with the requirements of Sub-clause 2213 (F) and no spraying shall be permitted except in small areas, or to make good a defective area caused by a blocked nozzle.

The nozzle shall be arranged to give a uniform spray and shall be tested prior to spraying by discharging on to suitable material (such as building paper, metal sheets, etc.,) or into special troughs made for this purpose. Testing shall not take place on the road, and any bitumen spilt on the ground shall be cleaned off.

If during spraying, a nozzle becomes blocked or develops a defect, the spraying shall be made good with a hand spray, and the machine repaired before further spraying is commenced.

When commencing and stopping spraying, sheets of building paper or metal at least 2 m wide shall be spread across the full width to be spread across the full width to be sprayed to give a clean sharp edge.

The metal sheets used for stopping and starting work shall be cleaned after each run and the troughs used for testing shall be cleaned at the end of each day's work.

During spraying all kerbs, road furniture, culvert headwalls, tree boles and the like which are liable to be disfigured by splashing of bitumen shall be protected, and any such feature which is accidentally marred by bitumen shall be cleaned off with a suitable solvent or made good.

E. Curing and Blinding of Prime Coat

If after application of the prime coat, the bituminous material fails to penetrate within the time specified or if the road must be used by traffic, blinding material shall be spread in the amount required to absorb any excess bituminous material and to protect the primed surface.

Blinding material shall be spread from trucks in such a manner that no wheel shall travel on uncovered bituminous material.

Unless the Engineer permits otherwise, all loose material on the sprayed surface, including any blinding material, shall be removed before any further layer of the pavement is laid.

F. Tolerances

The actual rate of application of bituminous binder across the width of each spray run shall not vary by more than ± 5% of the rate ordered and the actual of application of binder for each single run of the spray shall not vary from this specified rate by more than 0.03 liter per square meter.

G. Testing

Tray tests shall be taken at least twice a day during priming operation to check calculations based on dipping of spray trucks.

The minimum testing frequency for the purpose of process control shall be as given in the Table 8.8.

H. Measurement

Prime coat and Tack coat shall be measured in square meter. The road surface area on which the binding material is applied as prime coat or tack coat shall be measured in square meter by measuring the average width and length of the road section at intervals of 20 meters or as directed by the Engineer.

I. Payment

Emulsion/bitumen and cutter shall be paid at the respective contract unit rate which shall be the full and the final compensation for compliance of all requirements specified in Clause 2211 and 2212 in addition to those specified in Clause 115.

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2213 SURFACE DRESSING

A. Scope

This Clause covers the application of one or more coats of surface dressing, each coat consisting of a layer of bituminous binder sprayed on a based prepared previously, followed by a cover of stone chipping properly rolled to form a wearing course to the requirements of these Specifications.

A single surface dressing means an application of bituminous binder to the road surface followed immediately by a single layer of uniform sized chippings.

A multiple surface dressing means two or more surface dressing placed one on the other.

B. Materials

(i) Binder

The binder shall be either bitumen conforming to IS: 73 or rapid setting cationic bitumen emulsion (RS-2) conforming to IS: 8887. Grade of bitumen shall depend upon the climatic condition, for selection of grade of bitumen guidance may be taken from Table 22.10. The type of binder to be used shall be stated in the Contract, or as directed by the Engineer

(ii) Aggregates/ Chippings

The stone chips (cover aggregate) shall confirm the requirement as specified in Table 22.22. They shall be clean, hard, and durable, of cubical shape, free from dust and soft or friable matter, organic or other deleterious substances. Where the Contractor's selected source of aggregates has poor affinity for bitumen, the contractor shall produce test results that with the use of anti- stripping agents, the stripping value is improved to satisfy the specification requirements. The Engineer may approve such a source and as a condition for the approval of the source, the bitumen shall be treated with an approved anti-stripping agent, as per the manufacture's recommendations, at the cost of the contractor. The aggregate shall satisfy the requirements specified in Table 22.22.

Table 22.22: Physical Requirement of Aggregate for Surface Dressing

Property.	Test	Specification / Requirement	Test Method
Cleanliness (dust)	Grain size analysis	Max 1.5% passing 0.075 mm sieve	IS : 2386 (Part-1)
Particle shape	Combine Flakiness and Elongation Indices (Total)*	Max 35 %	IS : 2386 (Part-1)
Strength	Los Angeles Abrasion Value or Aggregate Impact Value	Max 35 5 Max 27 %	IS: 2386 (Part-4
Durability	Soundness: Sodium sulphate or Magnesium sulphate*	Max 12 % Max 18 %	IS: 2386 (Part-5)
Water Absorption	Water absorption*	Max 1%	IS: 2386 (Part-3)
Stripping	Coating and stripping of aggregate mix	Minimum retained coating 95 %	IS: 6241
Polishing	Polished Stone Value	Min 60	BS:812-114

- To determine this combined proportion, the flaky stone from a representative sample should first be separated out. Flakiness index is weight of flaky stone metal divided by weight of stone sample. Only the elongated particles be separated out from the remaining (non-flaky) stone metal. Elongation index is weight of elongated particles divided by total non-flaky particles. The value of flakiness index and elongation index so found are added up.

The size of aggregate shall depend upon the type of surface on which it is laid and the traffic intensity. The Table 22.23 May be used as guidance.

Table 22.23: Recommended nominal size of aggregate (chips) in mm

Type of surface	Traffic intensity in Terms of Number of vehicles per day in the lane under consideration		
	1000-2000	200- 1000	20-200
Very hard	10	6	6
Hard	13	10	6
Normal	13	10	6
Soft	19	13	13
Very soft		19	13

The grading requirements of chipping shall be as specified in the Table 22.24.

Table 22.24: Grading Requirements of Chippings

Sieve size (mm)	Percentage passing by weight			
	Nominal size			
	19	13	10	6
26.5	100			
19.5	85-100	100		
13.2	0-40	85-100	100	
9.5	0-7	0-40	85-100	100
5.6		0-7	0-35	85-100
4.75			0-10	
3.35				0-30
2.36	0-2	0-2	0-2	
0.6				0-10
0.075	0-1.5	0-1.5	0-1.5	0-1.5

The Engineer shall reject the chipping not conforming to be the above requirements.

C. Rate of Application of Binder and Chips

The rate of spray of binder and chips shall be depended upon the nominal size of the aggregate and the extent of its embedded into the surface. The rate shall be determined as per procedure given in “Overseas Road Note- 3, Guide to Surface Dressing in Tropical and Sub-tropical countries”. Approximate rate of application of aggregates, and binder under average condition are given in Table 22.25.

Table 22.25: Approximate Rate of Application of Binder and Aggregates

Nominal Aggregate size mm	Binder (kg/ sqm)			Aggregates cu.m/ sqm
	Uncoated Aggregates		Coated Aggregates	
	Bitumen	Emulsion	Bitumen	
19	1.2	1.8	1.0	0.014 – 0.015
13	1.0	1.5	0.8	0.009 – 0.011
10	0.9	1.3	0.7	0.007 – 0.009
6	0.75	1.1	0.6	0.003 – 0.005

Note: above rate of spray of Bitumen is excluding cutter and Anti-stripping agent, if applicable

The size and rate of spread of chippings shall be as specified in the Special Specification, BOQ or as instructed by the Engineer.

Tray tests shall be carried out at least twice per run during surface dressing operations to check spray and spread rates calculated from spray truck chippings and chip- spreader coverage, and more frequently when a number of short lengths are being surface dressed. Spray truck dipping and chip-spreader coverage shall be checked for each length sprayed.

D. Crushing, Screening, Washing and Stockpiling Chippings.

The construction plant provides and the methods of operating it, shall be such as to produce chippings which shall meet the specified requirements of Sub-clause 2213 (B) (ii). This may require washing the chippings to meet the cleanliness requirements.

The Contractor shall comply with Section 500 when chipping is stockpiled. If required, the stockpiles area shall be surfaced with 100 mm thickness of gravel or other material, acceptable to the Engineer. Any contaminated chippings shall not be used in the Works. After use the stockpile area shall be cleared, top soiled and left neat and tidy.

E. Pre-coated Chippings

The bituminous binder used for pre-coated chipping shall be a medium curing cut- back MC-30 or a semi-stable or stable emulsion unless otherwise instructed by the Engineer. The amount of bitumen binder used to Pre-coat chipping shall be specified in the Special Specification or shall be as instructed by the Engineer.

Pre-coating shall be carried out in a mixing machine acceptable to the Engineer. The pre-coated chipping shall not be tacky and liable to agglomerate. The chipping pre-coated with cut-back or emulsion shall be stockpiled for the lapse of time required by the solvents or water to evaporate.

The pre-coated chipping shall be kept free of contamination by dust or other deleterious matter.

F. Construction Plant for Pavement Works

(i) Bitumen Distributors

Bitumen distributors shall be truck mounted and shall have sufficient power to maintain uniform speeds for the proper application of the binder. The truck shall be equipped with an accurate tachometer showing the driver the speed in meters per minute. The truck shall be fitted with a gauge bar and chain or any other acceptable device clearly visible to the driver to enable him to follow the required edge. The distributor tank shall have a capacity of at least 4,000 liters and shall be fitted with a device for indicating the quantity in the tank at any time. It shall be equipped with heaters capable of maintaining temperatures up to 200°C and be fitted with an accurate thermometer.

The circulation system shall permit pumping around the tank and around the spray bar without actually spraying. Spray bars shall be available for spraying in widths varying from 0.5 m to 4 m and shall be adjustable transversely so that the operator can follow the required edge independently. The spray nozzles shall be arranged to give a uniform spray and the shut-off shall be quick-acting with an anti-drip device. The pressure in the spray bar shall be sufficient to give a good distribution and spraying of the binder.

Distributors shall be capable of applying bituminous binder within the limits of ± 5% of the specified rate of application over any portion of the surface.

Distributors shall be checked and calibrated before starting any work or when required by the Engineer. This shall include the calibration of all the metering devices and checking the uniformity of the transverse distribution of spray. All distributors shall be furnished with a “rate of spray/machine speed” chard.

(ii) Chip-spreaders

Mechanical chip-spreaders shall be capable of spreading the chippings uniformly over variable widths, from 0.5 to 3.5 m, at the rates specified.

The number and output of chip-spreaders shall be sufficient to ensure that chippings are spread immediately after the bituminous binder has been applied.

Chip-spreaders shall be checked and calibrated before starting any work or when required by the Engineer.

(iii) Rollers

The main rolling s**h**all be carried out with self-propelled pneumatic tyred rollers, having a wheel-load of more than 2 tons. The tyres shall be smooth and their pressure shall be more than 0.4 N/mm^2.

Where approved by the Engineer steel-wheeled rollers shall be used in tandem with pneumatic tyred rollers after all excess chippings have been removed and insufficiently chipped areas have been chipped over. Only steel-wheeled rollers weighing less than 8 tons (total weight) shall be accepted.

The number and output of rollers shall be sufficient to ensure that rolling does not lag behind spreading. To the extent possible, two pneumatic tyred rollers shall be used for each chip-spreader.

(iv) Miscellaneous Equipment

Sufficient trucks and loading machinery shall be employed to ensure an adequate, prompt and continuous supply of chippings.

Rubber tyred mechanical rotary brooms towed by or mounted on rubber tyred vehicles shall be provided. Tractor toed air compressor with sufficient length of hose pipes and air jet nozzle shall be provided to ensure sufficient cleaning of surface to be sprayed with bituminous layers.

G. Preparation of Surface

Immediately before spraying, all loose material and foreign matter shall be removed by thorough brushing with mechanical brooms and/or washing or by use of compressors or by other methods acceptable to the Engineer. All hardened mud or other foreign matter shall be loosened by scraping before sweeping. The debris shall be deposited well clear of the surface to be sprayed. Road furniture (manholes covers etc.) shall be covered with adhesive paper or similar materials. Kerb stones, roadside, and any other objects what shall not benefit from binder spray shall be protected in a manner approved by the Engineer.

Any defect of the surface shall be made good as instructed by the Engineer and no binder shall be sprayed until the surface has been approved by the Engineer. The Engineer's approval or otherwise of the surface shall be given immediately prior to the Contractor's intention to start spraying.

H. Application of Surface Dressing

(i) Application of Binder

The specified bitumen binder, cut back if instructed by the Engineer, its application rate and spraying temperature shall be instructed by the Engineer on site after design based on Traffic, Existing surface, climatic condition and type of chippings. The range of spraying Temperature for binder is normally within the range of 1400 to 1700 C.

The Contractor shall present his detailed program and arrangements and methods for the planning and execution of the surface dressing process to the Engineer for approval at least 28 days before he intends to commence this work. The Contractor's authorized representative shall be responsible for preparation of the programs and arrangements and the Contractor shall not commence surface dressing until the Engineer has approved his program

All operation associated with the surface dressing process shall be described in the Contractor's arrangements and shall include but not limited to;

- Method of bitumen supply, decanting, cutting back where required, heating and storing, transfer of distributor including list of equipment and capacities
- Location and method of production of cover aggregates and pre-coating with type and output of equipment, including crushers where appropriate; and
- Method of performing the surface dressing process including type and capacity/ weight of all main and ancillary items of equipment along with work force details.

The contractor shall provide, one day in advance his following day's surface dressing work program, including his expected spray lengths and widths for each run with details of the quantity of cover aggregate available in approved chip spreaders standing by at the commencement of the spray run. Spraying shall not commence until sufficient cover aggregate is in this position to cover the area programmed for spraying.

The distributor shall be filled with preheated bitumen binder on the same day, shortly before start of binder

application. The distributor spray bar and jets shall be preheated by circulating hot binder and the jets operated for at least 10 seconds for testing. The operation shall be carried out before each spray run, off road onto trays, or at a location where no environmental damage will be created. Jets shall be inspected by the Engineer for shape, direction, blockage or any other defects which shall be corrected before spraying is permitted. At the end of each spray run the distributor shall be driven off- road to avoid binder drip page on the pavement surface. Binder drip page from any location which may contaminate the road surface shall be sufficient for the Engineer to order removal of the offending source from the roadway until repairs are completed.

As emergency/ temporary measures, drip protection of the pavement surface shall be provided by use of buckets/ trays etc. These shall be available for use at all times, along with equipment for removal of binder spillages on the pavement surface, to the approval of the Engineer.

The Contractor shall carry out a trial section of surface dressing at a location instructed by the Engineer to demonstrate to the Engineer that this surface dressing operation is capable of constructing the surface dressing in accordance with Specification. The trial length shall be minimum 200 meters using full spray bar width with full width application of cover aggregate. If the trial section of surface dressing complies with the Specification, the Contractor shall receive payment for the Work in accordance with the Contract as if it were permanent Work. If the trial section of the surface dressing fails to comply with the Specification, the Contractor shall carry out further trials until his surface dressing operation complies with the Specification. No payment will be made for trial sections that do not comply with the Specification.

When the Engineer is satisfied that the Contractor is capable of constructing surface dressing that complies with the Specification after trial section, the Contractor will receive permission to commence surface dressing as permanent Work on the road pavement.

Application of binder shall only be under taken when the surface is dry or slightly damp, but no circumstances when wet, If in the opinion of the Engineer rainfall is likely before the application of binder or cover aggregate or the temperature or the pavement surface has time to fall below the specified minimum temperature (normally 150° C), the Engineer will instruct the Contractor to delay surface dressing work until weather conditions are satisfactory. Areas damaged by rainfall shall be rectified by the Contractor without additional payment, in a manner instructed by the Engineer.

If in the opinion of the Engineer the ambient temperature is too cold for surface dressing, the Contractor shall delay this operation until the temperature increases to the specified minimum level.

Building paper or other approved protective material shall be used at the start and finish of each spray run of sufficient width (not less than 600 mm) to enable the distributor to reach its calibrated road speed with spray jets open before discharging binder onto the pavement under treatment. Ends of previous surface treatment runs shall be trimmed back to clean, straight transverse edges and these shall form the start point for subsequent runs, with completed work suitably protected as described above. Spray runs will be limited to 300 meter length initially until the Contractor demonstrates his ability to plan and execute long length. Spray width shall be calculated allowing for 150 mm longitudinal overlap with adjacent passes and for the width that the following chipping spreader is able to cover. Longitudinal sprayed butt joints will not be permitted. The Contractor shall submit his spray width and length proposal to the Engineer for approval.

During spraying all passing traffic shall be stopped. If spray jets block, or the chipping spreader stops or any other event occurs which may affect the surface treatment process, then the spray bar operator immediately shall stop spraying. When the defective equipment or operation is rectified, spraying may restart with the Engineer's approval.

The distributor shall be dipped and the binder temperature recorded before and after each spray run and spray length and width recorded on approved record sheets. The hot application rate shall be calculated and recorded and checked against the specified rate. The calculated actual rate shall not vary by more than ± 5% from the specified rate. The actual quantity of binder sprayed corrected to 15.6^{o} C shall be calculated.

At least eight clean pre weighted metal spray trays shall be available for sampling the spray rate for each

spray run. To ensure that spray runs are parallel with the road pavement the road centerline or edge line shall be marked every 25 meters and string line laid out for the distributor driver to follow with the guide bar attached to his side of the cab.

Where a second surface dressing is specified, the first surface dressing shall be left open to traffic for a minimum period of 21 days and preferably a longer period before applying the second surface dressing unless special approval is obtained from the Engineer for a shorter period. Surplus chippings shall be removed by firm hand brooming or power brooming before applying the second surface dressing.

The spraying widths shall be so selected that the centerline joint of the second surface dressing is offset from that in the first surface dressing by minimum of 300 mm.

Hand pouring pots or hand lances shall be used to touch up carefully any parts of the first surface missed by the distributor/ Chipping spreader, or for the treatment of areas in which the distributor cannot operate and, in this case, only, chippings may be applied by an approved manual method. Areas damaged by excess bitumen or spillage of diesel or other deleterious material shall be repaired by careful cutting out and removed followed by careful hand poured or hand lance application of binder and chipping in a manner approved by the Engineer.

The second surface dressing shall be under taken when the first surface has been approved by the Engineer after all surplus chippings are removed, repairs carried out and the surface thoroughly cleaned as specified. The procedures to be followed are those specified for surface dressing in this Section.

(ii) Application of cover Aggregate

The cover aggregate shall be applied at the rate instructed by the Engineer on site in square meters of coverage per cubic meter of loose aggregate after design of the surface dressing.

The cover aggregate shall be applied immediately after the binder is applied and the approval of the Engineer may be applied slightly damp if not pre coated to depress dust and help adhesion. Aggregate applied to sprayed bitumen emulsion shall however be dry.

The cover aggregate shall be applied using approved mechanical spreaders, which shall be tailgate mounted on tipper trucks, pushed spreaders or self-propelled spreaders, specifically manufactured for the purpose and they shall preferably be metered. They shall be capable of uniformly spreading the same speed as the binder distributors during spraying.

The bitumen binder surface shall be covered with cover aggregate closely packed in one layer so that adjacent chippings are touching and no bitumen binder is left uncovered.

A sufficient number of loaded spreaders shall be available at the start of binder application to provide cover aggregate over the whole area programmed for spraying. The Contractor shall not commence spraying unless sufficient loaded spreaders are in place. Aggregate spreading by manual methods will not be permitted except in circumstances where

- Mechanical spreaders cannot operate effectively or safely
- Additional aggregate (back up work) is required
- Breakdown of mechanical spreaders occurs during the spreading operations before stoppage of spraying
- Minor surface repairs are instructed

The spreader shall follow the distributor at an interval not exceeding 10 m for hot binder work and not exceeding 5 m when using bitumen emulsion binder. A back-up vehicle or other approved means shall be constantly in attendance during surface dressing, from which additional aggregate may be hand applied to ensure complete and rapid coverage.

Where an adjoining pass of the distributor is required, no aggregate shall be applied to the binder over a 150-200 mm strip so as to permit subsequent overlap.

Under no circumstances will general brooming of the chipped surface be permitted. Aggregate spillage

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shall be removed with care and excess aggregate may be brushed off carefully after a minimum 3 days under traffic, after approval of the Engineer.

The cover aggregate shall be rolled with pneumatic multi- tyred power rollers. Pneumatic-tyred roller shall have a wheel load in the 1000 – 2000 kg range. Tyre pressure and sizes shall be in accordance with the manufacture's recommendations and shall be the same on each axle and tyres shall be smooth and in good condition to provide uniform rolling of chippings. The roller shall follow directly behind the spreader and shall continue to roll at speed of approximately 8-10 Kph, so as to provide minimum 6 passes over the entire treated area. Each pass shall overlap the previous pass by minimum half width of roller rolling shall be continued until all cover aggregate particle are firmly bedded. Tyres shall be in good condition and be kept clean and smooth to avoid pick-up of bitumen and chippings.

I. Aftercare and Control of Traffic

The road shall not be opened to traffic until the binder has attained sufficient viscosity to prevent the stones being whipped off.

The Contractor shall erect temporary traffic restriction signs, barriers and removable bumps or any other device, as instructed by the Engineer, to prevent vehicles traveling too fast over the newly laid surface dressing. Vehicle speed shall be restricted to a maximum of 30 km/h, until there is sufficient adhesion to ensure that the chippings shall not be dislodged by faster vehicles.

Where possible, the traffic shall be distributed across the road so as to obtain uniform polishing of the road surface.

After traffic has been permitted to run on the surface dressing for a period of at least two weeks and when instructed by the Engineer, all loose chippings shall be swept and taken away. Windrows of loose chipping shall not be allowed to accumulate at the sides of the road.

J. Rectification of Defects

If any defect in surface dressing work is found, the reasons of the defect shall be established and keeping them in view the defect shall be rectified as per direction of the Engineer. It required, the Engineer shall ask the contractor for redoing the defective portion.

The Contractor shall rectify or redo the defective work at his own expense.

K. Tolerance

The final average overall width of the surface dressing measured at six equidistant points over a length of 100 m shall be at least equal to the width specified or instructed. At no point shall the distance between the centerline of the road and the edge of the surface dressing be narrower than that instructed by more than 13 mm.

The actual rate of application of binder across the lane width shall not by more than ± 5% of the rate ordered and for each single run of the spray it shall not vary from the specified rate by more than 0.03 lit per square meter.

The actual rate of application of chipping along and across the lane width for each single run of the chip-spreader shall not vary by more than ± 5% of the rate ordered.

L. Testing

The minimum testing frequency required for the process control shall be as given in the table 8.8.

Routine inspection and testing shall be carried out to test the materials and workmanship for compliance with the requirements specified in this Section.

Any materials or workmanship not complying with the requirements specified, shall be replaced or redone with the materials or workmanship complying with the Specifications or, be repaired so as to comply with the requirements specified.

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M. Measurement

Each coat of surface dressing shall be measured as finished work for the area instructed to be covered, in square meters. Cover aggregate (Chipping) of each nominal size shall be measured as finished work in sq. m.

N. Payment

Surface dressings (One coat or two coat) shall be paid at their respective contract unit rate. Cover aggregate (chippings) of each nominal size as specified shall be paid at their respective contract unit rate. The Contract unit rate shall be the full and the final compensation for the cost of preparation of surface, to supply required quantity of binder, to receive binder, heating, mixing with cutter, spraying, rectification wherever required, compliance of all provisions specified in Clause 2211 and 2213 in addition to those specified in Clause 115.

2214 PENETRATION MACADAM, SEMI-GROUT

A. Scope

This work shall consist of compacted crushed coarse aggregates with application of bituminous binder and choke aggregate in accordance with the requirements of these Specifications. Reference shall be made to Clause 2211, as provisions contained therein shall be in this Clause also.

B. Materials

(i) Aggregate

The aggregate shall consist of crushed rock or crushed gravel. They shall be of angular shape and of such character that it shall compact and interlock under rolling. It shall be of reasonably uniform quality throughout and free from clay, earth, dust or other deleterious matter. It shall comply with the requirements specified in Table 22.26.

Table 22.26 Physical Requirement of Aggregate for Penetration Macadam

Los Angeles Abrasion (LAA)	Max. 40%
Aggregate Impact Value (AIV)	Max. 30%
Sodium Sulphate Soundness (SSS)	Max. 12%

The grading of coarse and choke aggregate shall be within the limits specified in the Table 22.27.

Table 22.27: Grading of Aggregate for Penetration Macadam

Sieve Size (mm)		Percentage passing by weight		
	Coarse aggregate (Course 75 mm thick)	Coarse aggregate (Course 75 mm thick)	Key Aggregate (type I)	Key Aggregate (type II)
75.00	100	-	-	-
63.00	90-100	100	-	-
53.00	20-55	90-100	-	-
37.50	0-15	40-75	-	-
26.50	-	15-35	-	-
19.00	0-15	0-15	100	100
11.20	-	0-5	90-100	90-100

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9.5	-	-	40-70	40-75
4.75	-	-	0-15	5-25
2.36	-	-	0-5	0-10
1.18	-	-	-	0-5

When the emulsion is used in place of bitumen the aggregate shall be of the composition as specified in the Table 22.28.

Table 22.28: Composition of Aggregate

Compacted thickness of Layer	Nominal single sized aggregate	Percentage
50 mm	37.5 mm	60%
	26.5 mm	30%
	13.2-19 mm	10%
65 mm – 75 mm	53 mm	60%
	37.5 mm	30%
	13.2-19 mm	10%

(ii) Binder

The binder shall be paving bitumen VG10 or similar, or cut-back bitumen or cationic or Anionic emulsion as specified in the Special Specification or in the Bill of Quantities.

C. Rate of Application of Binder and Aggregates

Unless otherwise specified the rate of spray of binder and aggregate shall be as given in the Tables 22.29 and 22.30.

Table 22.29: Rate of Application of Binder and Rate of Spread of Aggregate per sq.m

Compacted thickness	Binder	Coarse Aggregate	Key Aggregate
75 mm	5.2 litres	0.09 m^3	0.018 m^3
50 mm	3.5 litres	0.06 m^3	0.015 m^3

When emulsion is used, rate of application of emulsion shall be as specified in the Table 22.30.

Table 22.30: Rate of Application of Emulsion

Thickness of layer (mm)	Rate of application (lit/m^2)
50	3.0-5.5, (4.0) *
65	4.0-7.0, (5.5) *
75	5.5-8.0 (6.5) *

* Rate given in the bracket is the nominal rate of application.

D. Preparation of Existing Surface

The surface containing holes or depressions shall be repaired by removal of all loose materials and replacement with a suitable patching mixture or other material approved by the Engineer. This shall be compacted to produce a tight surface conforming to the adjacent areas. Bumps and waves which impair the riding qualities of the surface, shall be removed and required cross slope and grade shall be provided

by scarification and re-compaction or by other such means as shall be agreed or ordered by the Engineer. The base shall then be swept clean of all loose and foreign materials.

For use of emulsion clean sand or quarry fines shall normally be laid upon the prepared based to a depth not exceeding 13 mm.

E. Application of Coarse Aggregate

Immediately following preparation of the base (if this is not practicable the base must be re-cleaned of loose and foreign material) coarse aggregate shall be spread in loose depth so as to provide the specified thickness of surface course with required cross slope and grade after compaction. The aggregate shall be spread by hand or by an approved spreading device. Dumping in mass on the base shall not be permitted. The shallers at the edge of the surface course shall be prepared in advance of spreading the aggregate to allow the roller to roll the shaller edge and the edge of the loose aggregate simultaneously. Precautions shall be taken to prevent the coarse aggregate form becoming mixed or coated with earth or other deleterious matter both before and after spreading. The surface of the loose aggregate shall be carefully shaped and all high and low spots shall be remedied by removing or adding aggregate. The coarse aggregate shall then be dry rolled with a three-wheel roller weighing not less than 8.00 tons. Rolling shall start longitudinally at the sides and proceed towards the center of the pavement overlapping on successive passes by at least one half the width of the rear wheel. The compacted coarse aggregate shall then be tested with a straight-edge and camber template to ensure that it has a firm, even surface true to cross-section and having a texture which shall allow uniform penetration of the binder.

The aggregate shall be spread to the required contour and to such a thickness that, after being compacted its minimum thickness shall not be less than specified.

In case of hand spreading, each load of aggregate shall be unloaded outside the area upon which it is to be spread, and precaution shall be taken prevent the aggregate becoming contaminated with dust or foreign matter during the whole of the operations. The spreading shall be carried out with shovels and not with forks, care being taken to avoid segregation of the different sizes of aggregate. In case of mechanical spreading, the aggregate shall be spread by mechanical means such as a spreader box.

Where emulsion is used instead of bitumen, the aggregate of various sizes shall be thoroughly mixed and shaped before compaction. Alternatively, 14 mm to 20 mm materials may be spread over the larger material after the later has been placed in position and vibrated into the interstices. The minimum quantity of water shall be applied during rolling to bring up a slurry evenly in the aggregate within such a depth of the surface of the road as may be specified. It is preferable that the lower or slurred layer, which is thus water bound, shall not exceed two thirds of the total thickness of the compacted thickness of the aggregate.

F. Application of Binder

Binder shall be applied to the rolled coarse aggregate by means of an approved binder distributor complying with the requirements of Sub-clause 2213 (F) or such other means as the Engineer shall approve. The quantity of binder to be applied shall be as specified in Tables 22.29/22.30 and it shall be applied at the temperatures specified in Sub-clause 2211 (D). At the time of applying straight run bitumen or cut back bitumen binder, the aggregate shall be dry for the full depth of layer. When emulsion is used, the quantity of emulsion used shall be sufficient to coat the aggregate to the full depth of the layer above the slurred or water bound layer.

G. Application of Key Aggregate

Immediately after the binder has been applied to the coarse aggregate, key aggregate shall be sprinkled lightly over the surface in sufficient quantity to prevent sticking of the roller wheels. Then this shall be rolled and simultaneously with the rolling additional key aggregate shall be added in small quantities and lightly broomed over the surface while rolling continues until the surface interstices between the coarse aggregate have been filled but without covering the coarse aggregate itself. The surface shall then be rolled until the stone is thoroughly imbedded into the binder and anchored in place. Rolling shall be continued until the surface is hard and smooth and shows no perceptible movement under the roller.

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H. Protection of Pavement

The seal coat shall be applied as soon as practicable after the application of the choke aggregate and the surface course shall be protected from all traffic (other than that essential to the construction) until the completion of the seal coat.

I. Tolerances

Penetration macadam course shall be set out and constructed to the tolerances given in Clause 2202 of this Specification.

The actual rate of application of binder across the lane width shall not vary more than ±5% of the rate instructed and for each single run of the spray shall not vary from the specified rate by more than 0.03 liter per square meter.

The actual rate of application of chippings for each single run of the chip-spreader shall not vary by more than ±5% or the rate ordered.

J. Quality control

The minimum testing frequency for the purpose of process control shall be given in the table 8.8.

Routine inspection and testing shall be carried out to test the materials and workmanship for compliance with the requirements specified in this Section.

Any material or workmanship that does not comply with the requirements specified shall be replaced with materials and workmanship complying with the Specifications or, be repaired so that after being repaired it shall comply with the requirements specified.

K. Measurement

Penetration macadam course/Semi Grouting shall be measured as finished work in square meters.

L. Payment

The penetration macadam/ Semi Grouting shall be paid as per contract unit rate which shall be the full and the final compensation to the Contractor for the cost of preparation of existing surface, providing, hauling and spraying bituminous binder, coarse and choke aggregates and complying with Clauses 2211 and 2214 in addition to those specified in Clause 115.

2215 SEAL COAT

A. Scope

This Clause covers the materials, method of construction and requirements for the construction of seal coat with coarse sand and aggregates not more than 6mm in size.

B. Definition

A seal coat means an application of bituminous binder covered with fine aggregate/coarse sand as specified.

C. Materials

(i) Binder

The binder shall be a medium-curing cut-back MC-800 or MC-3000 or cationic emulsion unless otherwise specified.

(ii) Fine Aggregate

The aggregate shall consist of sand, or fine screenings free from organic matter, clay and other deleterious

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materials. The fines (passing a 0.425 mm sieve) shall be non- plastic. The grading shall be as specified in the Table 22.31.

Table 22.31: Grading of Aggregate

Sieve (mm)	Percentage passing by weight
9.50	100
4.75	70-90
2.36	45-70
0.60	15-35
0.15	0-2
0.075	0

The material shall be wet screened to ensure all material greater than 10mm is eliminated together with dust and foreign matter.

D. Rate of Application of Binder and Fine Aggregate

The rate of spray of binder and the rate of spread of the fine aggregate shall be as specified in the Special Specification or as provided in the BOQ or as instructed by the Engineer.

During the sand sealing operation tray tests to determine spray rate of binder and spread rate of fine aggregate shall be carried out at least twice per spray run.

E. Construction

The surface to be covered shall be prepared in accordance with Sub-clause 2213(G).

The binder shall be uniformly sprayed at the specified rate. After this, the fine aggregate as required shall be uniformly spread and rolled, all in accordance with Sub-clause 2213(H).

F. Aftercare and Control of Traffic

The road shall be opened to traffic when instructed by the Engineer. Traffic speed shall be restricted as per Sub-clause 2213(I) for as long as the Engineer may require. Any whipped-off aggregate shall be broomed back onto the road, as many times as are necessary for it to adhere fully to the binder.

G. Tolerance

Seal coat shall be constructed within the same width tolerance as given in Sub-clause 2213(K) for surface dressing.

The actual rate of application of binder across the lane width shall not vary be more than ±5% of the rate ordered and for each single run of the spray shall not vary from the specified rate by more than 0.003 liter per square meter.

The actual rate of application of fine aggregate along and across the lane width for each single run of the chip spreader shall not vary by more than ±5% of the rate ordered.

H. Quality control

The minimum testing frequency required for the test shall be as given in the Table 8.8.

Routine inspection and testing shall be carried out to test the materials and workmanship for compliance with the requirements specified in this Section.

Any materials or workmanship that does not comply with the requirements specified shall be replaced with materials and workmanship complying with the specifications or, be repaired so that after being repaired it shall comply with the requirements specified.

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I. Measurement

Seal coat shall be measured as finished work in square meter.

J. Payment

Payment for seal coat shall be as per contract unit rate which shall be the full and the final compensation for the cost of compliance of all requirements specified in Clause 2211 and 2215 in addition to those specified in Clause 115.

2216 BITUMINOUS MACADAM

A. Scope

This Clause comprises all the general requirements for bituminous Macadam. This work shall consist of construction in a single course having 50 mm to 100 mm thickness or in multiple courses of compacted crushed aggregates premixed with a bituminous binder on a previously prepared base to the requirements of these Specifications. Since then, Bituminous macadam is an open-graded mix, there is a potential that it may trap water or moisture vapour within the pavement system. Therefore, adjacent layer (shoulders) shall have proper drainage quality to prevent moisture-induced damage to the BM.

B. Materials

(i) Bitumen

The bitumen shall be viscosity graded paving bitumen complying with Indian Standard Specification for paving bitumen, IS: 73 or as specified in the Contract. The type and grade of bitumen to be used would depend upon the climatic conditions and the traffic. Guidelines for selection of bitumen are given in Table 22.10.

(ii) Coarse Aggregates

The coarse aggregates shall consist of crushed rock, crushed gravel or other hard material retained on· 2.36 mm sieve. It shall be clean, hard, durable and cubical shape, free from dust and soft organic and other deleterious substances. The aggregate shall satisfy the physical requirements specified in Table 22.32 Where crushed gravel is proposed for use as aggregate, not less than 90 percent by weight of the crushed material retained on 4. 75 mm sieve shall have at least two fractured faces resulting from crushing operation. Before approval of the source, the aggregates shall be tested for stripping. Where the Contractor's selected sources of aggregates have poor affinity for bitumen, as a condition for the approval of that source, the bitumen shall be treated with approved anti-stripping agents, as per the manufacturer's recommendations, without additional payment.

Table 22.32: Physical Properties of Coarse Aggregate

Property	Test	Requirement	Test method
Cleanliness	Grain size analysis	Max. 5% passing 0.075 mm	IS:2386 Part I
Particle shape	Combined Flakiness and Elongation Indices	Max. 35%	IS:2386 Part I
Strength	Los Angeles Abrasion Value or Aggregate Impact Value	Max. 40% Max. 30%	IS:2386 Part IV IS:2386 Part IV
Durability	Soundness (Sodium or Magnesium) Sodium Sulphate Magnesium Sulphate	5 cycles Max. 12% Max. 18%	 IS:2386 Part V IS:2386 Part V
Water absorption	Water absorption	Max. 2%	IS:2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate	Min. Retained Coating 95%	IS:6241
Water sensitivity	Retained Tensile strength*	Min. 80%	AASHTO 283

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(iii) Fine Aggregates

Fine aggregates shall consist of crushed or naturally occurring mineral material, or a combination of two, passing 2.36 mm sieve and retained on 75-micron sieve. It shall be clean, hard, durable, and free from dust and soft organic and other deleterious substances. Natural sand shall not be used in the binder course.

If the minimum retained tensile strength falls below 80 percent, use of anti-stripping agent is recommended to meet the minimum requirement.

(iv) Aggregate Grading and Binder Content

The combined grading of the coarse aggregates and fine aggregates, when tested in accordance with IS: 2386 Part 1, wet sieving method, shall conform to limits given in Table 22.33. The type and quantity of bitumen and appropriate thickness shall confirm to limit given in Table 22.33.

(v) Proportioning of Material

The combined aggregate grading shall not vary from the lower limit on one sieve to the higher limit on the adjacent sieve to avoid gap grading. The aggregate may be proportioned and blended to produce a uniform mix complying with the requirements in Table 22.33. The binder content shall be within a tolerance of± 0.3 percent by weight of total mix when individual specimens are taken for quality control tests in accordance with the provisions of table 8.8.

Table 22.33: Aggregate Grading and Bitumen Content

Grading	1	2
Nominal maximum aggregate size *	40 mm	19 mm
Layer thickness	80-100 mm	50-75 mm
IS Sieve size (mm)	Cumulative % by weight of total aggregate passing	
45	100	
37.5	90-100	
26.5	75-100	100
19	-	90-100
13.2	35-61	56-88
4.75	13-22	16-36
2.36	4-19	4-19
0.3	2-10	2-10
0.075	0-8	0-8
Bitumen content ** percent by mass of total mix	3.3**	3.4**

** Nominal maximum aggregate size is the largest specified sieve size upon which any of the aggregate material is retained.*

** Corresponds to specific gravity of the Aggregate being 2.7. In case aggregates have specific gravity more than 2.7, bitumen content can be reduced proportionately. Further, for regions where highest daily mean air temperature is 30°C or lower and lowest daily mean air temperature is -10°C or lower, the bitumen content may be increased by 0.5 percent.*

C. Construction Operation

(i) Weather and Seasonal Limitations

Clause 2211 (E) shall apply.

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(ii) Preparation of the Base

The base on which bituminous macadam is to be laid shall be prepared, shaped and compacted to the required profile in accordance with Clauses 2202 as appropriate, and a prime coat, shall be applied in accordance with Clause 2212 where specified, or as directed by the Engineer. The surface shall be thoroughly swept clean by a mechanical broom, and the dust removed by compressed air. In locations where mechanical broom cannot get access, other approved methods shall be used as directed by the Engineer.

(iii) Tack Coat

A tack coat in accordance with Clause 2212 shall be applied as required under the Contract or as directed by the Engineer.

(iv) Mixing and Transportation of the Mix

The provisions of Clauses 2211 shall apply.

(v) Laying

The provisions of Clause 2211 shall apply

(vi) Compaction

Compaction shall be carried out in accordance with the provisions of Clauses 2211. Rolling shall be continued until the specified density is achieved, or where no density is specified, until there is no further movement under the roller. The required frequency of testing is defined in the Table 8.8.

D. Surface Finish and Quality Control of Work

The surface finish of the completed construction shall conform to the requirements of Clause 2202. For control of the quality of materials and the works carried out, the relevant provisions of this specification shall apply.

E. Protection of the Layer

The bituminous macadam shall be covered with either the next pavement course or wearing course, as the case may be, within a maximum of forty-eight hours. If there is to be any delay, by the Contractor the course shall be covered by a seal coat before opening to any traffic. The seal coat in such cases shall be considered incidental to the work and shall not be paid for separately.

F. Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 115.

G. Measurement

Bituminous macadam shall be measured as finished work in cubic meters, or by weight in metric· tons, where used as regulating course, or square meters at the specified thickness as indicated in the Contract or shown on the drawings, or as otherwise directed by the Engineer.

H. Payment

Bituminous Macadam shall be paid as per contract unit rate which shall be the full and final compensation for the cost of compliance of all requirements of Clauses 2211 and 2216 in addition to those specified in Clause 115.

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2217 DENSE BITUMINOUS MACADAM

A. Scope

The specification describes the design and construction procedure for Dense Bituminous Macadam, (DBM), for. use mainly, but not exclusively, in base/binder and profile corrective courses. The work shall consist of construction in a single or multiple layers of DBM on a previously prepared base or sub-base. The thickness of a single layer shall be 50 mm to 100 mm.

B. Materials

(i) Bitumen

The bitumen shall be viscosity grade paving bitumen complying with the Indian Standard Specification IS: 73, modified bitumen complying with IS 15462 or as otherwise specified in the Contract.

The type and grade of bitumen to be used shall be specified in the Contract.

(ii) Coarse Aggregates

The coarse aggregates shall consist of crushed rock, crushed gravel or other hard material retained on 2.36 mm sieve. They shall be clean, hard, and durable, of cubical shape, free from dust and soft or friable matter, organic or other deleterious substances. Where the Contractor's selected source of aggregates has poor affinity for bitumen, the Contractor shall produce test results that with the use of anti-stripping agents, the stripping value is improved to satisfy the specification requirements. The Engineer may approve such a source and as a condition for the approval of that source, the bitumen shall be treated with an approved anti-stripping agent, as per the manufacturer's recommendations, at the cost of the Contractor. The aggregates shall satisfy the requirements specified in Table 22.34.

Where crushed gravel is proposed for use as aggregate, not less than 90 percent by weight of the crushed material retained on the 4.75 mm sieve shall have at least two fractured faces.

(iii) Fine Aggregates

Fine aggregates shall consist of crushed or naturally occurring mineral material, or a combination of the two, passing the 2.36 mm sieve and retained on the 75-micron sieve. These shall be clean, hard, durable, dry and free from dust, and soft or friable matter, organic or other deleterious matter. Natural sand shall not be allowed in binder courses. However, natural sand up to 50 percent of the fine aggregate may be allowed in base courses. The fine aggregate shall have a sand equivalent value of not less than 50 when tested in accordance with the requirement of IS: 2720 (Part 37). The plasticity index of the fraction passing the 0.425 mm sieve shall not exceed 4, when tested in accordance with IS: 2720 (Part 5).

(iv) Filler

Filler shall consist of finely divided mineral matter such as rock dust, hydrated lime or cement approved by the Engineer. The filler shall be graded within the limits indicated in Table 22.35.

The filler shall be free from organic impurities and have a plasticity Index not greater than 4. The Plasticity index requirement shall not apply if filler is cement or lime. Where the aggregates fail to meet the requirements of the water sensitivity test in Table 22.34, then 2 percent by total weight of aggregate, of hydrated lime shall be used and percentage of fine aggregate reduced accordingly.

(v) Aggregate Grading and Binder. Content

(i) When tested in accordance with IS:2386 Part 1 (wet sieving method), the combined grading of the coarse and fine aggregates and filler for the particular mixture shall fall within the limits given in Table 22.36 for grading 1 or 2 as specified in the Contract. To avoid gap grading, the combined aggregate gradation shall not vary from the lower limit on one sieve to higher limit on the adjacent sieve.

Table 22.34: Physical Requirements for Coarse Aggregate for Dense Bituminous Macadam

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Property	Test	Specification	Method of Test
Cleanliness (dust)	Grain size analysis	Max 5% passing 0.075 mm sieve	IS:2386 Part I
Particle shape	Combined Flakiness and Elongation Indices*	Max 35%	IS:2386 Part I
Strength	Los Angeles Abrasion Value or Aggregate Impact Value	Max 35% Max 27%	IS:2386 Part IV
Durability	Soundness either: Sodium Sulphate or Magnesium Sulphate	Max 12% Max 18%	IS:2386 Part V
Water Absorption	Water Absorption	Max2%	IS:2386 Part Ill
Stripping	Coating and Stripping of Bitumen Aggregate Mix	Minimum retained coating 95%	IS:6241
Water Sensitivity	Retained Tensile Strength**	Min. 80%	AASHTO 283

- To determine this combined proportion, the flaky stone from a representative sample should first be separated out. Flakiness index is weight of flaky stone metal divided by weight of stone sample. Only the elongated particles are separated out from the remaining (non-flaky) stone metal. Elongation index is weight of elongated particles divided by total non-flaky particles. The values of flakiness index and elongation index so found are added up.
- If the minimum retained tensile test strength falls below 80 percent, use of anti- stripping agent is recommended to meet the requirement.

Table 22.35: Grading Requirements for Mineral Filler

IS sieve (mm)	Cumulative Percent Passing by Weight of Total Aggregate
0.6	100
0.3	98-100
0.075	85.-100

Table 22.36: Composition of Dense Graded Bituminous Macadam

Grading	1	2
Nominal aggregate size*	35.5 mm	26.5 mm
Layer thickness	75-100	50-75
IS Sieve[1] (mm)	Cumulative % by weight of total aggregate passing	
45	100	
37.5	95-100	100
26.5	63-93	90-100
19	-	71-95
13.2	55-75	56-80
9.5	-	-
4.75	38-54	38-54
2.36	28-42	28-42
1.18	-	-
0.6	-	-
0.3	7-21	7-21
0.15	-	-
0.075	2-8	2-8
Bitumen content % by mass of total mix	Min 4.0**	Min 4.5**

** The nominal maximum particle size is the largest specified sieve size upon which any of the aggregate*

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is retained.

** Corresponds to specific gravity of aggregates being 2.7. In case aggregate have specific gravity more than 2. 7, the minimum bitumen content can be reduced proportionately. Further the region where highest daily mean air temperature is 30°C or lower and lowest daily air temperature is - 10°C or lower, the bitumen content may be increased by 0.5 percent.*

(ii) Bitumen content indicated in Table 22.36 is the minimum quantity. The quantity shall be determined in accordance with sub-Clause (C) below.

C. Mix Design

The bitumen content required shall be determined following the Marshall Mix design procedure contained in Asphalt Institute Manual MS-2.

The Fines to Bitumen (F/B) ratio by weight of total mix shall range from 0.6 to 1.2.

(i) Requirements for the Mix

Apart from conformity with the grading and quality requirements (or individual ingredients, the mixture shall meet the requirements set out in Table 22.37.

Table 22.37: Requirements for Dense Graded Bituminous Macadam

Properties	Viscosity Grade Paving Bitumen	Modified bitumen		Test Method
		Hot climate	Cold climate	
Properties	75 blows on each face of the specimen			
Minimum stability (kN at 60 °C)	9.0	12.0	10.0	AASHTO T245
Marshall flow (mm)	2-4	2.5-4	3.5-5	AASHTO T245
Marshall Quotient (Stability Flow)	2-5	2.5-5		MS-2 and ASTM 02041
% air voids	3-5			
% Voids Filled with Bitumen (VFB)	65-75			
Coating of aggregate particle	95% Minimum			IS:6241
Tensile Strength ratio	80% Minimum			AASHTO T 283
% Voids in Mineral Aggregate (VMA)	Minimum percent voids in mineral aggregate (VMA) are set out in Table 13.30			

(ii) Binder Content

The binder content shall be optimized to achieve the requirements of the mix set out in Table 22.37. The binder content shall be selected to obtain 4 percent air voids in the mix design. The Marshall method for determining the optimum binder content shall be adopted as described in the Asphalt Institute Manual MS-2.

Where maximum size of the aggregate is more than 26.5 mm, the modified Marshall method using 150 mm diameter specimen described in MS-2 and ASTM D 5581 shall be used. This method requires modified equipment and procedures. When the modified Marshall test is used, the specified minimum stability values in Table 22.37 shall be multiplied by 2.25, and the minimum flow shall be 3 mm.

Table 22.38: Minimum Percent Voids in Mineral Aggregate (VMA)

Nominal Maximum Particle Size (mm)	Minimum VMA Percent Related to Design Percentage Air voids		
	3.0	4.0	5.0
26.5	11.0	12.0	13.0
37.5	10.0	11.0	12.0

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- *Note: Interpolate minimum voids in the mineral aggregate (VMA) for designed percentage air voids values between those listed.*

(iii) Job Mix Formula

The Contractor shall submit to the Engineer for approval at least 21 days before the start the work, the job mix formula proposed for use in the works, together with the following details:

(a) Source and location of all materials;

(b) Proportions of all materials expressed as follows:

1. Binder type, and percentage by weight of total mix;
2. Coarse aggregate/Fine aggregate/Mineral filler as percentage by weight of total aggregate including mineral filler;

(c) A single definite percentage passing each _sieve for the mixed aggregate;

(d) The individual grading of the individual aggregate fraction, and the proportion of each in the combined grading;

(e) The results of mix design such as maximum specific gravity of loose mix (Gmm), compacted specimen densities, Marshall stability flow, air voids, VMA, VFB and related graphs and test results of AASHTO T 283 Moisture susceptibility test;

(f) Where the mixer is a batch mixer; the individual weights of each type of aggregate, and binder per batch;

(g) Test results of physical characteristics of aggregates to be used;

(h) Mixing temperature and compacting temperature.

While establishing the job mix formula, the Contractor shall ensure that it is based on a correct and truly representative sample of the materials that will actually be used in the work and that the mix and its different ingredients satisfy the physical and strength requirements of these Specifications. Approval of the job mix formula shall be based on independent testing by the Engineer for which samples of all ingredients of the mix shall be furnished by the Contractor as required by the Engineer.

The approved job mix formula shall remain effective unless and until a revised Job Mix Formula is approved. If a change in the source of materials be proposed, a new job mix formula shall be forwarded by the Contractor to the Engineer for approval before the placing of the material.

(iv) Plant Trials - Permissible Variation in Job Mix Formula

Once the laboratory job mix formula is approved, the Contractor shall carry out plant trials to establish that the plant can produce a uniform mix conforming to the approved job mix formula. The permissible variations of the individual percentages of the various ingredients in the actual mix from the job mix formula to be used shall be within the limits as specified in Table 22.39 and shall remain within the gradation band. These variations are intended to apply to individual specimens taken for quality control tests in accordance with specification.

Table 22.39: Permissible Variations in the Actual Mix from the Job Mix Formula

Description	Base/binder Course
Aggregate passing 19 mm sieve or larger	± 8%
Aggregate passing 13.2 mm, 9.5 mm	±7%
Aggregate passing 4.75 mm	±6%
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	±5%
Aggregate passing 0.3 mm, 0.15 mm	±4%
Aggregate passing 0.075 mm	±2%

Binder content	± 0.3%
Mixing temperature	± 10°C

(v) Site trials

Once the plant trials have been successfully completed and approved, the Contractor shall carry out laying trials, to demonstrate that the proposed mix can be successfully laid and compacted all in accordance with Clause 2211.

The laying trial shall be carried out on a suitable area which is not to form part of the works. The area of the laying trials shall be a minimum of 100 sq.m of construction similar to that of the project road, and it shall be in all respects, particularly compaction, the same as the project construction, on which the bituminous material is to be laid.

The Contractor shall previously inform the Engineer of the proposed method for laying and compacting the material. The plant trials shall then establish if the proposed laying plant, compaction plant, and methodology is capable of producing satisfactory results. The density of the finished paving layer shall be determined by taking cores, no sooner than 24 hours after laying, or by other approved method. The compacted layers of Dense Graded Bituminous Macadam (DBM) shall have a minimum field density equal to or more than 92% of the density based on theoretical maximum specific gravity (Gmm) obtained on the day of compaction in accordance with ASTM D 2041.

Once the laying trials have been approved, the same plant and methodology shall be applied to the laying of the material on the project, and no variation of either shall be acceptable, unless approved in writing by the Engineer, who may at his discretion require further laying trials.

D. Construction Operations

(i) Weather and Seasonal Limitations

The provisions of Clause 2211 (E) shall apply.

(ii) Preparation of Base

The base on which Dense Graded Bituminous Material is to be laid shall be cleaned off all loose materials and foreign matter with mechanical brooms or by other approved methods. Any defect of the surface shall be made good no bituminous mix shall be laid until the surface has been approved by the Engineer.

(iii) Geo synthetics

Where Geo synthetics are specified in the Contract, this shall be in accordance with the requirements stated in Section 1500.

(iv) Stress Absorbing Layer

Where a stress absorbing layer is specified in the Contract, this shall be applied in accordance with the requirements of crack prevention courses.

(v) Prime Coat

Where the material on which the dense bituminous macadam is to be laid is other than a bitumen bound layer, a prime coat shall be applied, as specified, in accordance with the provisions of Clause 2212, or as directed by the Engineer.

(vi) Tack Coat

Where the material on which the dense bituminous macadam is to be laid is either bitumen bound layer or primed granular layer, tack coat shall be applied, as specified, in accordance with the provisions of Clause 2212, or as directed by the Engineer.

(vii) Mixing and Transportation of the Mix

The provisions as specified in Clauses 2211 shall apply. Clause 2211 gives the mixing, laying and rolling

temperature for dense mixes using Paving bitumen. In case of modified bitumen, the temperature of mixing and compaction shall be higher than the mix with viscosity grade bitumen. The exact temperature depends upon the type and amount of modifier used and shall be adopted as per the recommendations of the manufacturer. In order to have uniform quality, the plant shall be calibrated from time to time.

(viii) Laying

The provisions of Clauses 2211 shall apply.

(ix) Compaction

The general provisions of Clauses 2211 shall apply, as modified by the approved laying trials. The compaction process shall be carried out by the same plant, and using the same method, as approved in the laying trials, which may be varied only with the express approval of the Engineer in writing.

E. Opening to Traffic

It shall be ensured that the traffic is not allowed without the approval of the Engineer in writing, on the surface until the dense bituminous layer has cooled to the ambient temperature.

F. Surface Finish and Quality Control of Work

The surface finish of the completed construction shall conform to the requirements of Clause 2202. All materials and workmanship shall comply with the provisions of these Specifications.

G. Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 104.

H. Measurement

Dense Bituminous Macadam shall be measured as finished work either in cubic meters, tons or by the square meter at a specified thickness as indicated in the Contract drawings, or documents, or as otherwise directed by the Engineer.

I. Payment

Dense Graded Bituminous Macadam shall be paid as per contract unit rate which shall be the full and final compensation for the cost of compliance of all requirements of Clauses 2211 and 2217 in addition to those specified in Clause 115.

2218 ASPHALT CONCRETE/ BITUMINOUS CONCRETE

A. Scope

This Clause covers the materials, method of construction and requirements for the construction of Asphalt Concrete. / Bituminous concrete

This work shall consist of construction of Bituminous Concrete, for use in wearing and profile corrective courses. This work shall consist of construction in a single layer of bituminous concrete on a previously prepared bituminous bound surface. A single layer shall be 30 mm/40 mm/50 mm thick

B. Material

(i) Bitumen

The bitumen shall be viscosity grade paving bitumen complying with the Indian Standard Specification IS: 73, modified bitumen complying with IS: 15462 or as otherwise specified in the Contract.

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(ii) Coarse Aggregates

The coarse aggregates shall be generally as specified in Clause 2216 (B), except that the aggregates shall satisfy the physical requirements of Table 22.40 and where crushed gravel is proposed for use as aggregate, not less than 95 percent by weight of the crushed material retained on the 4.75 mm sieve shall have at least two fractured faces.

Table 22.40: Physical Requirements for Coarse Aggregate for Bituminous Concrete

Property	Test	Specification	Method of Test
Cleanliness (dust)	Grain size analysis	Max 5% passing 0.075 mm sieve	IS:2386 Part I
Particle shape	Combined Flakiness and Elongation Indices	Max 35%	IS:2386 Part I
Strength	Los Angeles Abrasion Value or Aggregate Impact Value	Max 30% Max 24%	IS:2386 Part IV
Durability	Soundness either: Sodium Sulphate or Magnesium Sulphate	Max 12% Max 18%	IS:2386 Part V
Polishing	Polished Stone Value	Min 55	BS:812-114
Water Absorption	Water Absorption	Max 2%	IS: 2386.Part Ill
Stripping	Coating and Stripping of Bitumen Aggregate Mix	Minimum retained coating 95%	IS: 6241
Water Sensitivity	Retained Tensile Strength*	Min 80%	AASHTO 283

* *If the minimum retained tensile test strength falls below 80 percent, use of anti- stripping agent is recommended to meet the requirement.*

(iii) Fine Aggregates

The fine aggregates shall be all as specified in Clause 2217 (B) (iii).

(iv) Filler

Filler shall be as specified in Clause 2217 (B) (iv).

(v) Aggregate Grading and Binder Content

When tested in accordance with IS: 2386 Part 1 (Wet grading method), the combined grading of the coarse and fine aggregates and filler shall fall within the limits shown in Table 22.41. The grading shall be as specified in the Contract.

Table 22.41: Composition qty. Bituminous Concrete Pavement Layers

Grading	1	2
Nominal aggregate size*	19 mm	13.2 mm
Layer thickness	50 mm	30-40 mm
IS Sieve[1] (mm)	Cumulative % by weight of total aggregate passing	
45		
37.5		
26.5	100	
19	90-100	100
13.2	59-79	90-100
9.5	52-72	70-88

4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content % by mass of total mix	Min 5.2*	Min 5.4**

Notes:

* *The nominal maximum particle size is the largest specified sieve size up on which any of the aggregate is retained.*

*** Corresponds to specific gravity of aggregate being 2.7. In case aggregate have specific gravity more than 2. 7, the minimum bitumen content can be reduced proportionately. Further the region where highest daily mean air temperature is 30°C or lower and lowest daily air temperature is - 10°C or lower, the bitumen content may be increased by 0.5 percent*

C. Mix Design

(i) Requirements for the Mix

Clause 2217 (C) (i) shall apply.

(ii) Binder Content

Clause 2217 (C) (ii) shall apply.

(iii) Job Mix Formula

Clause 2217 (C) (iii) shall apply.

(iv) Plant Trials - Permissible Variation in Job Mix Formula

The requirements for plant trials shall be as specified in Clause 2217 (C) (iv), and permissible limits for variation as given in Table 22.42

Table 22.42: Permissible Variations in Plant Mix from the Job Mix Formula

Description	Permissible Variation
Aggregate passing 19 mm sieve or larger	±7%
Aggregate passing 13.2 mm, 9.5 mm	±6%
Aggregate passing 4.75 mm	±5%
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	±4%
Aggregate passing 0.3 mm, 0.15 mm	±3%
Aggregate passing 0.075 mm	±1.5%
Binder content	± 0.3%
Mixing temperature	± 10°C

(v) Laying Trials

The requirements for laying trials shall be as specified in Clause 2217 (C) (v). The compacted layers of bituminous concrete (BC) shall have a minimum field density equal to or more than 92 percent of the

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average theoretical maximum specific gravity (Gmm) obtained on the day of compaction in accordance with ASTM 02041.

D. Construction Operations

(i) Weather and Seasonal Limitations

The provisions of Clause 2211(E) shall apply.

(ii) Preparation of Base

The surface on which the bituminous concrete is to be laid shall be prepared in accordance with Clause 2207 and 2202 as appropriate, or as directed by the Engineer. The surface shall be thoroughly swept clean by mechanical broom and dust removed by compressed air. In locations where a mechanical broom cannot get access, other approved methods shall be used as directed by the Engineer.

(iii) Geosynthetics

Where Geosynthetics are specified in the Contract, this shall be in accordance with the requirements stated in Section 1500.

(iv) Stress Absorbing Layer

Where a stress absorbing layer is specified in the Contract, this shall be applied in accordance with the requirements of relevant specification.

(v) Tack Coat

The provisions as specified in Clause 2212 shall apply.

(vi) Mixing and Transportation of the Mix

The provisions as specified in Clause 2207 shall apply.

(vii) Laying

The general provisions of Clauses 2211 shall apply, as modified by the approved laying trials.

(viii) Compaction

The general provisions of Clauses 2211 shall apply, as modified by the approved laying trials.

E. Opening to Traffic

Provisions in Clause 2216(D) shall apply.

F. Surface Finish and Quality Control

The surface finish of the completed construction shall conform to the requirements of Clause 2202. All materials and workmanship shall comply with the provisions set out in these Specifications.

G. Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 104.

H. Measurement

Asphalt concrete/ Bituminous concrete of specified grading in contract document shall be measured as finished work either in cubic meters, tons or by the square meter at a specified thickness as indicated in the Contract drawings, or contract documents, or as otherwise directed by the Engineer

I. Payment

Asphalt concrete/ Bituminous concrete shall be paid as per contract unit rate which shall be the full and

final compensation for the cost of compliance of all requirements of Clauses 2211 and 2218 in addition to those specified in Clause 115.

2219 CLOSE-GRADED PREMIX SURFACING/MIXED SEAL SURFACING

A. Scope

(a) The work shall consist of the preparation, laying and compaction of a close graded premix surfacing material of 20 mm thickness composed of graded aggregates premixed with a bituminous binder on a previously prepared surface, in accordance with the requirements of these Specifications, to serve as a wearing course.

(b) Close graded premix surfacing shall be of Type A or Type B as specified in the Contract documents. Type A. grading is recommended for use in areas having rainfall more than 150 cm per year. In other areas Type B grading may be used.

B. Materials

(i) Binder

The binder shall be viscosity grade bitumen of a suitable grade as specified in the Contract, or as directed by the Engineer, and satisfying the requirements of IS: 73. For selection of grade of bitumen guidance may be taken from Table 22.10.

(ii) Coarse Aggregates

The aggregates shall conform to Clause 2218(B) (ii) except that the water absorption shall be limited to a maximum of 1 percent. The Polished Stone Value, shall not be less than 55, when tested as per BS: 812-114.

(iii) Fine Aggregates

The fine aggregates shall consist of crushed rock, or natural sand or a mixture of both. These shall be clean, hard, durable, un-coated, mineral particles, dry; and free from injurious, soft or flaky particles and organic or deleterious substances.

(iv) Aggregate Gradation

The coarse and fine aggregates shall be so graded or combined as to conform to one or the other grading's given in Table 22.43, as specified in the contract.

Table 22.43: Aggregate Gradation

IS Sieve Designation (mm)	Cumulative Percent by Weight of Total Aggregate Passing	
	Type A	Type B
13.2	-	100
11.2	100	88-100
5.6	52-88	31-52
2.8	14-38	5-25
0.090	0-5	0-5

(v) Proportioning of Materials

The total quantity of aggregates used for Type A or B close-graded premix surfacing shall be 0.27 cubic meter per square meter area. The quantity of binder used for premixing shall be 22.0 kg and 19.0 kg per 10 square meter area for Type A and Type B surfacing respectively.

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C. Construction Operations

(i) Weather and Seasonal Limitations

The provisions of Clause 2211(E) shall apply.

(ii) Preparation of Surface

The underlying surface on which the bituminous surfacing is to be laid shall be prepared, shaped and conditioned to the specified lines, grade and cross-section in accordance with Clause 2203. A prime coat where needed shall be applied in accordance with Clause 2212 as directed by the Engineer.

(iii) Tack Coat

A tack coat complying with Clause 2212, shall be applied over the base preparatory to laying of the surfacing.

(iv) Preparation of Premix

Hot mix plant of appropriate capacity and type shall be used for the preparation of the mix material. The hot mix plant shall have separate dryer arrangement for heating aggregate.

The temperature of the binder and aggregate at the time of mixing, laying and compaction shall be in conformity with the temperature given in Table 22.14. The difference in temperature between the binder and aggregate shall at no time exceed 14°C. Mixing shall be thorough to ensure that a homogeneous mix is obtained in which all particles of the aggregates are coated uniformly.

The mix shall be immediately transported from the mixer to the point of use in suitable vehicles or hand barrows. The vehicles employed for transport shall be clean and the mix being transported covered in transit if so directed by the Engineer.

(v) Laying and Compaction

The pre mixed material shall be spread on a previously prepared base to Clause 2211 by a paver unless specified otherwise in the Contract to the desired thickness, grades and cross fall (camber). The cross-fall shall check by means of camber boards and irregularities levelled out. Excessive use of blades or rakes shall be avoided. As soon as sufficient length of bituminous material has been laid, rolling shall commence with 8- 10-ton rollers, smooth wheel tandem type or other approved equipment. Rolling shall begin at the edge and progress towards the center longitudinally, except that on super elevated and uni-directional cambered portions, it shall progress from the lower to upper edge parallel to the center line of the pavement. When the roller has passed over the whole area once, any high spots or depressions, which become apparent, shall be corrected by removing or adding premixed materials. Rolling shall then be continued until the entire surface has been rolled and c: ill the roller marks eliminated. In each pass of the roller the preceding track shall be overlapped uniformly by at least one third width. The roller wheels shall be kept damp to prevent the premix from adhering to the wheels. In no case shall fuel/lubricating oil be used for this purpose. Excess use of water for this purpose shall also be avoided.

Rollers shall not stand on newly laid material. Rolling operations shall be completed in every respect before the temperature of the mix falls below the rolling temperature indicated in Table 22.14.

D. Opening to Traffic

Traffic may be allowed after completion of the final rolling when the mix has cooled down to the surrounding temperature. Speed restrictions may be imposed at initial stages.

E. Surface Finish and Quality Control of Work

The surface finish of construction shall conform to the requirements of Clause 2203. For control on the quality of materials and the works carried out, the relevant provisions of specification shall apply.

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F. Arrangements for Traffic

During the period of construction, arrangements for traffic shall be in accordance with the provisions of Clause 104.

G. Measurement

Close-graded premix surfacing, Type A or B shall be measured as finished work, for the area specified to be covered, in square meters at a specified thickness. The area will be the net area covered.

H. Payment

Close-graded premix surfacing, Type A or B shall be paid as per contract unit rate which shall be the full and final compensation for the cost of compliance of all requirements of Clauses 2211 and 2219 in addition to those specified in Clause 115.

2220 OPEN-GRADED PREMIX SURFACING

I. Open-Graded Premix Surfacing using Viscosity Grade Paving Bitumen

A. Scope

This work shall consist of preparation, laying and compaction of an open-graded premix surfacing material of 20 mm thickness composed of small-sized aggregate premixed with bituminous binder on a previously prepared base, in accordance with the requirements of these Specifications to serve as a wearing course.

B. Materials

(i) Binder

The binder shall be viscosity grade bitumen of a suitable grade as specified in the Contract, or as directed by the Engineer, and satisfying the requirements of IS: 73. For selection of grade of bitumen guidance may be taken from Table 22.10.

(ii) Aggregates

The aggregates shall conform to Clause 2216(B) except that the water absorption shall be limited to a maximum of 1 percent. The Polished Stone Value, shall not be less than 55, when tested as per BS: 812-114.

(iii) Proportioning of Material

The materials shall be proportioned in accordance with Table 22.44.

Table 22.44 Quantities of Materials Required for 10 m2 of Road Surface for 20 mm Thick Open-graded Premix Surfacing

Material		Quantity
Aggregates		
a	Nominal Stone size 13.2 mm (passing 22.4 mm sieve and retained on 11.2 mm sieve)	0.18 m^3
b	Nominal Stone size 11.2 mm (passing 13.2 mm sieve and retained on 5.6 mm sieve)	0.09 m^3
	Total	0.27 cum
Binder		
a	For 0.18 m3 of 13.2 mm nominal size stone of 52 kg bitumen per m^3	9.5 kg
b	For 0.09 m3 of 11.2 mm nominal size stone of 56 kg bitumen per m^3	5.1 kg
	Total	14.6 kg

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C. Construction Operations

(i) Weather and Seasonal Limitations

Clause 2211 (E) shall apply.

(ii) Preparation of Surface

The underlying surface on which the bituminous surfacing is to be laid shall be prepared, shaped and conditioned to the specified lines, grade and cross-section in accordance with Clause 2202. A prime coat where needed shall be applied in accordance with Clause 2212 as directed by the Engineer.

(iii) Tack Coat

A tack coat complying with Clause 2212, shall be applied over the base preparatory to laying of the surfacing.

(iv) Preparation of Premix

Hot mix plant of appropriate capacity and type shall be used for the preparation of the mix material. The hot mix plant shall have separate dryer arrangement for heating aggregate.

The temperature of the binder and aggregate at the time of mixing, laying and compaction shall be in conformity with the temperature given in Table 22.14. The difference in temperature between the binder and aggregate shall at no time exceed 14°C. Mixing shall be thorough to ensure that a homogeneous mix is obtained in which all particles of the aggregates are coated uniformly.

The mix shall be immediately transported from the mixer to the point of use in suitable vehicles or hand barrows. The vehicles employed for transport shall be clean and the mix being transported covered in transit if so directed by the Engineer

(v) Spreading and Rolling

The pre mixed material shall be spread on a previously prepared base by a paver or as directed by the Engineer to the desired thickness, grades and cross fall (camber). The cross-fall shall be check by means of camber boards and irregularities levelled out.

Excessive use of blades or rakes shall be avoided. As soon as sufficient length of bituminous material has been laid, rolling shall commence with 8–10-ton rollers, smooth wheel tandem type or other approved equipment. Rolling shall begin at the edge and progress towards the center longitudinally, except that on super elevated and uni-directional cambered portions, it shall progress from the lower to upper edge parallel to the center line of the pavement. When the roller has passed over the whole area once, any high spots or depressions, which become apparent, shall be corrected by removing or adding premixed materials. Rolling shall then be continued until the entire surface has been rolled and c: ill the roller marks eliminated. In each pass of the roller the preceding track shall be overlapped uniformly by at least one third width. The roller wheels shall be kept damp to prevent the premix from adhering to the wheels. In no case shall fuel/lubricating oil be used for this purpose. Excess use of water for this purpose shall also be avoided.

Rollers shall not stand on newly laid material. Rolling operations shall be completed in every respect before the temperature of the mix falls below the rolling temperature indicated in Table 22.14.

(vi) Seal Coat

A seal coat conforming to specification of the type specified in the Contract shall be applied to the surface immediately after laying the surfacing.

D. Opening to Traffic

No traffic shall be allowed on the road until the seal coat has been laid. In the case of Type B seal coat, traffic may be allowed soon after final rolling when the premixed material has cooled down to the surrounding temperature. In the case of Type A seal coat, traffic shall not be permitted to run on any newly sealed area until the following day. In special circumstances, however, the Engineer may open the road to

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traffic immediately after rolling, but in such cases, traffic shall be rigorously limited to 20 km per hour until the following day.

E. Surface Finish and Quality Control of Work

The surface finish of construction shall conform to the requirements of Clause 2203. For control of the quality of materials and the works carried out, the relevant provisions of specification shall apply.

F. Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 104.

G. Measurement

Open graded premix surfacing shall be measured as finished work, for the area instructed to be covered, in square meters.

H. Payment

Open-graded premix surfacing shall be paid as per contract unit rate which shall be the full and final compensation for the cost of compliance of all requirements of Clauses 2211 and 2220 in addition to those specified in Clause 115.

II. Open Graded Premix Surfacing Using Cationic Bitumen Emulsion

A. Scope

This work shall consist of the preparation, laying and compaction of an open graded premix surfacing of 20 mm thickness composed of small-sized aggregate premixed with a cationic bitumen emulsion on a previously prepared surface, in accordance with the requirements of these Specifications to serve as a wearing course.

B. Materials

(i) Binder

The binder for Premix wearing course shall be Cationic Bitumen emulsion of Medium Setting (MS) grade complying with IS: 8887 or as specified in the Contract.

(ii) Aggregate

The requirements of Clause 2216 (B) shall apply.

C. Proportioning of Materials

The materials shall be proportioned as per quantities given in Tables 22.45.

Table 22.45: Quantities of Aggregate for 10 sq. m Area

Aggregates		
a)	Coarse aggregate nominal 13.2 mm size, passing IS 22.4 mm sieve and retained on IS 11.2 mm sieve	0.18 m^3
b)	Coarse aggregate nominal 11.2 mm size; passing IS 13.2 mm sieve and retained on IS 5.6 mm sieve	0.09m^3
	Binder	20 to 23 kg

D. Construction Operations

(i) Weather and Seasonal Limitations

Clause 2211(E) shall apply except that the minimum air temperature for laying shall be 10°C. Cationic bitumen emulsions shall not normally be stored below 0°C.

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(ii) Preparation of Surface

The underlying surface on which the bituminous surfacing is to be laid shall be prepared, shaped and conditioned to the specified lines, grade and cross-section in accordance with Clause 2203. A prime coat where needed shall be applied in accordance with Clause 2212 as directed by the Engineer.

(iii) Preparation of Binder

Before opening, the cationic bitumen emulsion drums shall be rolled at a slow speed, to-and-fro for at least 5 times, for a distance of about 10 meters, to distribute any storage sedimentation.

(iv) Tack Coat

A tack coat complying with Clause 2212, shall be applied over the surface preparatory to laying of the surfacing where specified in the Contract, as directed by the Engineer.

(v) Preparation of Premix

Premixing of cationic bitumen emulsion and aggregates can be carried out in a suitable mixer such as cold mixing plant as per IS: 5435 (Revised) or concrete mixer or by pay loaders in exceptional cases where approved by the Engineer. Where specified in the Contract, continuous mixing operation shall be done either in batch or continuous hot mix plant suitable for emulsion mixes.

When using concrete mixer for preparing the premix, 0.135 cu.m (0.09 cu.m of 13.2 mm size and 0.045 cu.m of 11.2 mm size) of aggregates per batch shall be used. This quantity will be for 5 sq.m of road surface with 20 mm average thickness.

The aggregates required for one batch shall be prepared adjacent to the mixer.

The coarse aggregate of 13.2 mm size shall be placed into the mixer followed by 5 to

6.5 kg of Cationic bitumen emulsion and then the 11.2 mm size aggregate shall be added, followed by 5 to 6.5 kg of Cationic bitumen emulsion. After the materials have been mixed thoroughly, the mix shall be, immediately transported to the laying site in suitable vehicles. Too much mixing shall be avoided.

(vi) Spreading and Rolling

The premixed cationic bitumen emulsion and aggregates shall be spread uniformly by a paver within 10 minutes of applying the tack coat. All levelling, raking etc. shall be complete within 20 minutes of the time of mixing. The mix shall be spread uniformly to the desired thickness, grades and cross fall (camber). The cross fall shall be checked by means of camber boards and irregularities levelled out. Too much raking is to be avoided.

The rolling shall start immediately after laying the premix. A smooth wheeled tandem roller of 8-10 tons shall be used, unless other compaction methods are approved by the Engineer, based on the results of laying trials, if necessary. While rolling, wheels of roller shall be clean and kept moist to prevent the premix from adhering to the wheels. In no case shall fuel/ lubricating oil be used for this purpose. Use of water for this purpose shall be strictly limited to an absolute minimum.

Rolling shall commence at the edges and progress towards the center longitudinally except in the case of super elevated and unidirectional cambered sections where rolling shall be carried out from the lower edge towards the higher edge parallel to the center line of the road.

After one pass of roller over the whole area, depressions or uncovered spots shall be correct by adding premix material. Rolling shall be continued until the entire surface has been rolled, to maximum compaction and all the roller marks eliminated. In each pass of the roller, the preceding track shall be overlapped uniformly by at least one- third width. Roller(s) shall not stand on newly laid material. Joints, both longitudinal and transverse to the road sections laid and compacted earlier, shall be cut vertically to their full depth so as to expose fresh surface which shall be painted with a thin coat of binder before the new mix is laid.

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E. Seal Coat

A seal coat, conforming to relevant specification, as specified in the Contract, shall be applied immediately after laying the premix carpet.

F. Opening to Traffic

Traffic shall not be allowed over the premix surface till seal coat is laid. After the seal coat is laid, traffic may be allowed in accordance with Clause 2215.

G. Surface Finish and Quality Control

The surface finish of construction shall conform to the requirements of Clause 2203. For control of the quality of materials and work carried out, relevant provision of Section 300 shall apply.

H. Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 104.

I. Measurement

Open graded premix surfacing shall be measured as finished work, for the area instructed to be covered, in square meters.

J. Payment

Open-graded premix surfacing shall be paid as per contract unit rate which shall be the full and final compensation for the cost of compliance of all requirements of Clauses 2211 and 2220 in addition to those specified in Clause 115.

2221 BITUMINOUS COLD MIX BITUMINOUS MACADAM (INCLUDING COLD MIXED SEMI DENSE BITUMINOUS CONCRETE)

A. Scope

This Clause covers the materials, method of construction and requirements for the construction of Bituminous cold mix bituminous macadam (CMBM) and Cold mixed semi dense Bituminous concrete (CMSDBC).

B. Definition

Bituminous Macadam (BM) is an open graded bituminous mixture suitable for moderate traffic roads used for construction of bituminous base course as well as for strengthening of flexible pavements. Cold Mixed Bituminous Macadam (CMBM) shall involve construction of one or more courses of compacted mixture prepared with bitumen emulsion and mineral aggregate, laid immediately after mixing to required grade and camber using appropriate machinery

Semi dense bituminous concrete (SDBC) is a continuously graded mix, which can be used as binder course or wearing course in a flexible pavement.

C. Materials

(i) Binder

Bitumen emulsion for preparation of CMBM shall be Medium Setting (MS), Slow Setting (SS-2) grade or a tailor made for compatibility with available mineral aggregates, conforming to IS: 8887 or other international standard (ASTM or AASHTO). The actual grade of the emulsion to be used would depend on the characteristics of the aggregates. If the sand equivalent value of the aggregates is between 50 to 70, use SS-2 grade of emulsion and for sand equivalent values more than 70, use MS grade of emulsion. The

Rapid Setting (RS-1) grade of bitumen emulsion, conforming to IS: 8887 shall be used in Tack Coat.

The general guide for selection of binder is given in. Table 22.12.

(ii) Aggregates

The aggregates shall comply with the requirements of Clause 2217 the aggregates shall consist of crushed stone, crushed slag, crushed gravel (shingle) or other suitable. The aggregates shall be clean, strong, durable and fairly cubical, free from clay and disintegrated pieces, organic and other deleterious matter. The coarse aggregates shall be crushed material retained on 2.36 mm IS sieve while fine aggregates shall be fraction passing, 2.36 mm sieve and retained on 75-micron sieve. The aggregate shall satisfy the physical requirements as given in Table 22.30 with sand equivalent value of more than 50. The requirement of filler (material passing 75-micron sieve) in CMBM shall be met from stone dust, cement, hydrated lime or any other non-plastic mineral matter. The blended aggregates for CMBM shall satisfy the grading given in Table 22.46.

Table 22.46: Grading Requirement of Combined Aggregate

Sieve Size (mm)	Percentage passing by weight	
	for 50 mm thick CMBM	for CMSDBC
26.5	100	
19.0	90-100	
13.2	56-88	100
9.5	20-55	90-100
4.75	16-36	35 - 51
2.36	4-19	24 - 39
1.18		15-30
0.3	2-10	9-19
0.075	1- 4	2-8
Sand Equivalent Value (ASTM D 2419)	50 minimum	50 minimum
Percent Crushed Faces	75 % minimum	75 % minimum
Bitumen Emulsion % by weight of Mix	5 % minimum	8 – 10 %

D. Mix Design

The detailed procedure for mix design shall be as specified in appendix -9 of IRC: SP: 100. The mix shall meet the requirement shown in Table 22.47.

Table 22.47: Design Requirement for Cold Mix

Parameter	Cold Mix Bituminous Macadam (CMBM)	Cold Mixed Semi Dense Bituminous Concrete (CMSDBC)
Number of compactions blows on each side of Marshall specimen	50	50
Marshall Stability at 25°C in kg (minimum), after curing the specimen at room temperature for 72 hours	350	500
Marshall flow (mm)	Max 8	Max 8
Per cent voids in mixture	10 - 14	6 - 10

Binder content (residual bitumen) by weight of total mix (%), min	3.5	4.5
Retained indirect tensile strength at 25°C after conditioning for 72 hours in air and 72 hours at 40°C, in water %	50	75

Method for Design of Cold Mixes

The cold mix design procedure involves optimization of water as well as content of bitumen emulsion for the aggregates in the mix. The aggregates are made moist with water to wet its surface and then coated with cationic bitumen emulsion. The different sizes of aggregates are blended in proportions to achieve the best standard gradation of BM or SDBC. The following steps are necessary to design cold mixed BM or SDBC with cationic bitumen emulsion:

(i) Testing of aggregate:

The aggregates supplied are subjected to sieve analysis and other physical tests for determining the properties such as specific gravity, aggregate impact value, water absorption and sand equivalent value.

(ii) Testing of bitumen emulsion:

The samples of slow setting bitumen emulsion (SS-2) to be used for construction of BM shall be tested as per IS: 8887. The coating test of aggregates shall also be carried out as per ASTM D 2397 or AASHTO M 208.

(iii) Determination of premixing water content:

For determination of optimum water content for premixing, the quantity of bitumen emulsion is first determined using the following equation.

$P = 0.05A+0.1B+0.5C$ ... (1)

Where,

P = Quantity of bitumen emulsion (%)

A = Percent aggregate retained on 2.36 mm sieve

B = Percent aggregate passing 2.36 mm sieve and retained on 90-micron sieve C = Percent aggregate passing on 90-micron sieve

Different samples of aggregates and emulsion mixes are prepared keeping the quantity of bitumen emulsion constant (as determined from Equation 1) and varying the water content. The coated aggregates are then visually observed for coated area of the aggregate by the binder. The optimum water content is the water content at which maximum coating of aggregate occurs. This water content is taken as premixed water content in designing the cold mixed BM or cold mixed SDBC. The optimum water content for BM or SDBC is normally found to be 2 to 3 percent by weight of aggregate. However, this quantity may vary depending on the weather condition (temperature, humidity and wind velocity) and properties of aggregates

Determination of Optimum Binder Content

The procedure for the design of cold mix utilizes standard Marshall Equipment. Marshall Test specimens in triplicate are prepared with different binder content (bitumen emulsion). Different sizes of aggregates are blended to achieve the specified aggregate gradation. About 1100 gm of graded aggregates are made wet uniformly with optimum water content. The different percentage of bitumen emulsion, say 5 percent by weight of aggregate, are then added to the aggregates and mixed for 1-2 minutes for achieving uniform binder coating. The mixture is dried for about 1 -2 hours using a fan. The cold mix is then kept in oven at 40°C for 2 hours. The cold mix is then transferred into the Marshall mould with a filter paper on base plate and compacted with 50 blows of Marshall Hammer on both faces. Similarly, the Marshall specimen is prepared with optimum water content and bitumen emulsion contents of 5, 6, 7, 8 and 9 percent by weight of aggregates. The Marshall specimens are then extracted from the mould after 24 hours and cured in air

oven at 40°C for 72 hours before subjecting to different Marshall Stability Tests. Marshall Specimen are subjected to different tests viz. bulk density, stability and flow values. Marshall Stability and flow values are determined in dry state at 25°C. Different properties of the mixes are determined and other design parameters like voids content, voids filled with binder etc. are calculated.

E. Construction Procedure

(i) Weather and Seasonal Limitation

CMBM/ CMSDBC shall not be laid during raining or when the granular base course is wet or when the atmospheric temperature in the shade is below 8°C.

(ii) Preparation of the Base

All equipment necessary for the proper construction work shall be available at the work site in good working condition. Adequate provisions for safe movement of vehicular traffic shall be made in advance. The underlying surface on which CMBM/CMSDBC is to be laid shall be prepared, shaped and conditioned to a uniform grade and camber. Depressions, ruts or potholes shall be repaired in advance at least before the day of laying. The surface of underlying course shall be thoroughly swept, made clean free from the dust and foreign materials. If the existing base is extremely uneven, a profile correction course may be considered.

(iii) Tack Coat

The tack coat with emulsion shall be applied not earlier than 10 minutes before laying the cold mix.

(iv) Preparation and Transportation of the Mix

It is imperative to prepare cold mix of proper and uniform quality by using a cold mix plant or a modified hot mix plant switching off the heating. The production of high-quality cold mixes requires a well-controlled operation. The set up for a central cold mix plant may vary depending on the quality required and the type of mix. It is recommended that the plant shall have (1) a twin shaft pug mill, (2) a tank for emulsion storage, (3) metered pumps for emulsion transfer to pug mill and water, valves and spray bars, (4) aggregate feeder bins, (5) conveyor belts for moving aggregate and mix, and (6) a power source. The pug mill shall allow a variation in the mixing time to ensure proper coating of aggregate with emulsion. The use of a surge bin or storage silo is desirable for continuous mixing and improved mix uniformity. Batch type pug mills can be used but the production of cold mixes is ideally suited for continuous type mixers. The ingredients shall be mixed for about one minute to achieve the uniform coating of bitumen on mineral aggregates. Excessive mixing may un-coat the aggregates.

(v) Spreading and Compaction

For plant produced cold mixes, the paving procedures are similar to those used for hot bituminous mixes. The self-propelled pavers are recommended. Cold mixes are generally stiffer than hot mixes or not as workable as hot mixed materials, with open- graded mixture being the most difficult to place. Proper paver operation is thus very critical for obtaining a uniform and smooth mat. This includes keeping the paver speed as constant as possible and the level of mix on the augers at a nearly constant depth. If the mix sticks to paver screed or tearing of the mat occurs, a change in the mixing time or the water content shall be adjust, which eliminate the problem. The screed should not be heated.

For an open-graded mix like the CMBM, the breaking of bitumen emulsion usually occurs quickly. With open-graded mixes, rolling may normally begin immediately behind the paver. Vibratory rolling for open-graded mixes is not recommended because fracture of aggregate and bitumen debonding may occur. A light "choke" or "blotter" of a coarse sand or fine crusher screenings may be applied after steel-wheeled rolling. The choke or blotter permits rolling with a pneumatic-tired roller and prevents pick-up of mix and damage of compacted cold mix layer by the traffic. Properly designed uniformly cold mix shall be discharged to the tippers for transportation to site. The spreading of cold mix will be done preferably by means of a self-propelled mechanical paver at a suitable speed capable of spreading, tamping and finishing to the proper grade, line and cross-section. The mix shall be spread in such a manner that, after

compaction, the required thickness of surfacing layer is achieved. The paver laid cold mix, after becoming black from original brown colour due to breaking of emulsion on surface of aggregate, shall be thoroughly and uniformly compacted by a set of rollers at a speed not more than 5 km per hour. The break down rolling shall be done with 8-12 tonne three-wheel steel roller and the final rolling shall be done with 8- 10 tonne tandem roller. Before finishing rolling by tandem roller, break down rolling shall preferably be followed by an intermediate rolling with smooth wheel pneumatic roller of 15 -30 tonne capacity having a tyre pressure of 7 kg/cm2 the wheels of the roller shall be kept moist to prevent the picking up of mix. Rolling shall commence longitudinally from edges and progress towards the center except on super elevated portions, where it shall progress from lower to the upper edge. Rolling shall be continued till the specified density is achieved and all roller marks are eliminated. Traffic shall be allowed after 2-3 hours, when the cold mix is well set and is not picked up by the vehicles.

F. Quality Control

Adequate quality control at every stage of the work is essential. Therefore, field laboratory must be set up. Periodic sieve analysis of each type of mineral aggregate shall be done to ensure that the gradation of aggregate follows close to the original gradation of designed job mix. The number of samples to be taken per day would depend upon the bulk supply of aggregates made in a day at the plant site. The characteristics of mineral aggregate shall be determined at the rate of one test for every 100 m3 of aggregates. Periodic checks of the properties of emulsion such as residue content, viscosity and residue on 600 micron IS sieve shall be done in field, in accordance to IS: 8887-2004. At least one sample for every 100 tonnes of cold mix discharged at the pug mill chute or a minimum of one sample per plant per day shall be collected and various tests shall be carried out. These specimens shall be tested for density. Residual bitumen shall be extracted from mix after curing and emulsion shall be determined.

For the compacted surface of every 700 m^2 or less, one field density test shall be conducted to determine the density of mix as laid and compacted. The density shall not be less than 95 percent of the maximum laboratory density. The longitudinal profile of the finished surface shall be tested by 3 m straight edge, parallel to the center line, and the transverse profile by a camber template. Any irregularity greater than 6 mm shall be corrected.

G. Measurement

Bituminous cold mix bituminous macadam (CMBM) / Cold mixed semi dense Bituminous concrete (CMSDBC) shall be measured in cubic meter calculated as the product of the length and the compacted cross-sectional area of the cold mix laid as per Drawing or by weight in metric tonne or by square meter at a specified thickness as specified in the Contract.

H. Payment

Bituminous cold mix bituminous macadam (CMBM) / Cold mixed semi dense Bituminous concrete (CMSDBC) shall be paid as per contract unit rate which shall be the full and the final compensation for the cost of compliance of all requirements specified in Clause 2211 and 2221 in addition to those specified in Clause 115.

2222 OTTA SEAL

A. Scope and Definition

This Clause covers the supply and application of single or double Otta Seal with or without sand cover seal, each layer consisting of bituminous binder sprayed on a previously prepared base/sub-base surface, followed by graded aggregates properly rolled to form a wearing course to the requirements of these Specifications. A single Otta Seal means an application of bituminous binder to the road surface followed immediately by a single layer of graded aggregates.

A double Otta Seal means two Otta Seal surfacing placed over base/sub-base. Sand cover seal is normally applied over single Otta seal surfacing.

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B. Materials

(i) Aggregates

a. General

The preferred aggregate grading will, to some extent, depend on the traffic volume at the time of construction, as well as during the two months immediately following the sealing operation, as this contributes significantly in forming the Otta Seal.

The following materials are recommended for Otta Seal aggregates;

- Screened natural gravel from weathered granitic rocks;
- Crushed and screened gravel from sandstone and lake deposits;
- Screened river/lake gravel; and sand
- Crushed, screened rock from a variety of rock types such as igneous rocks and pedogenic deposits of calcrete and silcrete.

All the aggregates must be clean and must be free from heavily plastic fines and other foreign material.

Screened natural gravel

As-dug' gravel shall be used after screening to remove oversize particles and excessive fines. Low moisture content in the material is desirable to avoid clogging of the finer mesh of the sieve.

Crushed aggregate

Crushed gravel

Crushing of natural gravel allows a better utilization of the gravel source and generally improves the quality of the aggregate. The gravel size greater than 4.75mm shall have three faces broken.

Crushed Rock

The crushed rock material acceptable in the base course layer can be used to produce aggregate of required grading for an Otta Seal surfacing.

b. Sand cover seal

Material for a sand cover seal used in Otta Seals can be crusher dust, river sand or fine pit sand or a combination of these materials. The material shall be free from organic matter and lumps of clay and shall be non-plastic. All material shall pass the 6.7 mm sieve.

c. Maximum particle size

The preferred maximum particle size is 16 mm for single Otta seal but a maximum particle size of 19 mm can be accepted in the first layer where a double seal is to be constructed.

d. Fines content

The amount of fines shall not exceed 10%. A higher fines content may result in construction problems as the binder tends to coat the finer particles before the larger ones, and may lead to a less durable surfacing with inferior surfacing characteristics.

e. Grading and aggregate strength requirements and their selection

The grading requirements for an Otta Seal shall be any one as in the Table 22.48 below.

Table 22.48: Grading Envelopes

Sieve sizes (mm)	Open Grading (% passing)	Medium Grading (% passing)	Dense Grading (% passing)
16	100	100	100

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13.2	52-82	68-94	84-100
9.5	36-58	44-73	70-98
6.7	20-40	29-54	54-80
4.75	10-30	19-42	44-70
2.00	0-8	3-18	20-48
1.18	0-5	1-14	15-38
0.425	0-2	0-6	7-25
0.075	0-1	0-2	3-10

The strength requirements of aggregates for Otta Seal shall be as shown in Table 22.49.

Table 22.49: Aggregate Strength Requirements

Test	Requirement	Test method
Los Angles Abrasion value Or Aggregate Impact value	40 percent (Max) 30 percent (Max)	IS: 2386 (Part – 4) IS: 2386 (Part – 4) or IS: 5640

The selection of preferred aggregate grading shall be as shown in the Table 22.50.

Table 22.50: Preferred Aggregate Grading

AADT	Best suited grading
Less than 100	Open
100 – 1000	Medium
More than 1000	Dense

AADT Best suited grading Less than 100 Open, 100 – 1000 Medium, more than 1000 Dense The grading curve for the Otta Seal aggregate shall fall smoothly within the envelope detailed in Table 22.48.

It is recommended that the graded aggregates, which fall within medium envelopes, shall be used as the aggregates in an Otta Seal for rural road in Nepal. However, all types of aggregates falling within the open and medium grading envelopes may be used as aggregate in an Otta Seal, provided the binder viscosity and spray rates are tailored accordingly. The type of grading to be used shall be advised by the Engineer.

f. Flakiness

The flakiness index for natural gravel (river gravel) or mixture of crushed and natural gravel in an Otta Seal is not specified except for crushed aggregate for which the flakiness index shall not exceed 35. The weighted Flakiness Index is determined on the following fractions: 9.5 – 13.2mm, 6.7 – 9.5mm and 4.75 – 6.7mm.

g. Plasticity Index

The Plasticity Index of the fraction passing 0.425mm mesh sieve shall be maximum 5%. Non-plastic is however preferable.

h. Aggregate application rates

It is important to apply sufficient amount of aggregate to ensure that there is some surplus material during rolling and through initial curing period of the seal. It also reduces the risk of bleeding. After the embedment of aggregates any excess aggregates can be swept off. The aggregate embedment will normally take about 2-3 weeks to be achieved for crushed aggregates, whereas the initial curing period for natural gravel will be considerably longer (6 – 8 weeks).

However, the application rates for Otta Seal aggregates and crusher dust/sand for cover seal shall fall

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within the ranges given in Table 22.51.

Table 22.51: Aggregate Application Rates

Type of seal	Aggregate spread Rates (m^3/m^2)		
	Open Grading	Medium Grading	Dense Grading
Otta Seals	0.013 – 0.016	0.013 – 0.016	0.016 – 0.020
Sand cover seals	Sand cover seals 0.010 – 0.012		

To reduce the risk of bleeding application rates may very often be increased to the satisfaction of the Engineer.

(ii) Binders

a. General

The binder shall be 150/200 penetration grade bitumen or MC 3000 cutback bitumen or MC 800 cutback bitumen as specified in the Bill of Quantities from a source approved by the Engineer. MC 3000 cutback bitumen shall be used in warm weather. In cold weather, when night temperatures are likely to fall below 10° C, MC 800 cutback grade bitumen may be used. The blending of cutback bitumen shall be carried out on site to produce required medium curing cutback by mixing kerosene in the proportion as mentioned in the Table 22.52.

Table 22.52: Typical blending proportions to produce medium curing cut- back bitumen

Required Product	Cutter (kerosene) in percent of total mixture	
	VG 10 base bitumen	150/200 base bitumen
150/200	3-5% (flux oil is used instead of cutter)	-
MC 3000	8 - 10% *	5 - 8%
MC 800	18 - 20 % *	15-18%

* The durability of binder can be improved by replacing 3% - of the cutter with flux oil where the VG 10 grade is used as base bitumen. Unused or used engine oil is suitable as flux oil. Excessive fluxing which may cause disintegration of the seal is prohibited and will be rejected.

An Otta Seal will in most cases require a cutter that produces medium curing (MC) cutback bitumen. Kerosene is normally preferred among the cutting oils producing MC cutback bitumen.

b. Preparation of cut back bitumen

Cut back bitumen can be prepared for use in Otta Seal as follows:

The cut back bitumen grades can be made by blending 80/100 pen/ VG 10, grade on site using the following proportions:

To make 150/200 pen. Grade: 3 -5% softener mixed with 95 – 97% VG 10. Softener can be a purpose to petroleum distillate, alternatively engine oil, old or new. In addition, 3% of kerosene shall be used.

The cut back bitumen grades can be made by blending 150/200 pen. Grade on site using the following proportions:

To make MC 3000: 5-8% kerosene mixed with 92-95% 150/200pen grade. To make MC 800: 15-18% kerosene mixed with 82-85% 150/200 pen grade.

Circulation in the tank shall be carried out for at least 1 hour after mixing. Diesel shall not be used for cutting to MC grades.

c. Choice of binder

Paving bitumen shall NEVER be used in Otta Seals unless softened or cut back to meet the viscosity

requirements as given in Table 22.53.

Table 22.53: Selection of Binder:

AADT at the time of construction	Type of bitumen					
	Open grading		Medium grading			Dense grading
More than 1000	Not applicable		150/200 Grade		pen.	MC 3000, MC 800 in cold weather
100-1000	150/200 Grade	pen.	150/200 Grade weather	in	pen. cold	MC 3000, MC 800 in cold weather
Less Than 100	150/200 Grade	pen.	MC 3000			MC 800

d. Storage and Spraying Temperatures of Binder

Recommended temperature for storage and spraying of binders are shown in Table 22.54.

Table 22.54: Temperature for storage and spraying of binder

Bitumen Product	Storage temp. ^{0} C		Spraying Temp. ^{o}C
	< 24 hours	> 24 hours	
150/200	165	115	165-180
MC 3000	155	100	135-155
MC 800	120	75	110-135

The heating temperature of bitumen or cutback shall not in any case be greater than the spraying temperature. Heating of bitumen by the use of firewood is strictly prohibited. Any bitumen or cutback overheated shall be removed from the site and disposed off by the contractor in an environmentally friendly manner acceptable to the Engineer.

e. Binder spray rates

The binder spray rates in hot condition for un-primed base/sub-base course shall be as per Table 22.55:

Table 22.55: Bituminous binder spray rate (Lit/ sqm)

Grading Type of Otta Seal		Open	Medium	Dense	
				AADT < 100	AADT > 100
Double	1st layer (*)	1.6	1.7	1.8	1.7
	2nd layer (*)	1.5	1.6		1.9
Single, with a sand cover seal	Crusherdust or coarse river sand	0.9	0.8	2.0	0.7
	1st layer (*)	1.6	1.7	2.0	1.9
Single (*)		1.7	1.8	2.0	-
Maintenance reseal (single)		1.5	1.6	1.8	1.7

(*) On a primed base course the spray rate shall be reduced by 0.2 l/m2 in the first layer.

Notes:

- Where the aggregate has a water absorbency of more than 2 %, the bitumen spray rate shall be increased by 0.3 l/m^2
- Binder for sand cover seal shall be MC 3000 for crusher dust or course river sand, MC 800 for fine sand.
- No correction of binder spray should be made to compensate for the solvent used in the cutback bitumen.

f. Anti-Stripping Agent

When anti-stripping agent is required it shall be added to the bitumen immediately before the start of spraying operations and shall be circulated for a minimum period of 30 minutes prior to spraying. Anti-stripping agent that has been kept hot in the bitumen distributor for more than five hours shall be considered stale. An additional dosage would then be required, amounting to half of the originally specified percentage.

g. Prime

Priming of base courses made of non-calcareous material is normally not required for Otta Seals. However, when using calcrete of any type in the base course, priming is warranted due to the high amount of bitumen absorption.

Prime shall be applied in accordance to the Clause 2212 of the Specifications

(iii) Construction

(i) Granular bases of non-calcareous materials do not normally require a prime, unless otherwise directed by the Engineer. Calcrete bases shall be primed.

(ii) The sealed surface shall receive not less than 15 passes of a pneumatic tyred roller on the day of sealing. On the same day, the Engineer may direct one pass with a 10-12 tonnes heavy flat steel roller. During the following 2 days, the entire sealed area, including the shoulders, shall receive a further minimum of 15 passes daily, unless otherwise approved by the Engineers. A minimum of two pneumatic tyred rollers with a minimum weight of 12 tonnes shall be used for rolling operations.

(iii) The Engineer may direct even trafficking of the surfaced area and channeling of the traffic may be required for certain periods and traffic cones or similar may be required.

(iv) The road shall be open to traffic immediately after the sealing operations are completed, but a maximum speed limit of 50km /h shall be enforced during the initial 2 -3 weeks after construction.

(v) Aggregate that has been dislodged by traffic during the immediate post construction period shall be broomed back into the exposed areas during the first 2-3 weeks, as directed by the Engineer

(vi) After 2-3 weeks of trafficking the excess aggregate shall be swept off the road surface and speed limitations can be lifted, unless otherwise directed by the Engineer. If natural gravel is used with a fairly high content of fines, the period may be extended to 6 weeks of as directed by the Engineer.

(vii) A team shall be retained on site to deal with areas of bleeding if required. The team will be required during the normal construction period as well as during the first season following the completion of sealing operations.

(viii) A minimum period of 8-12 weeks shall normally elapse between construction of the subsequent layers of the surfacing, and during that period the road shall receive as much heavy trafficking as possible, unless otherwise directed by the Engineer.

(ix) Prior to applying the sand cover seal, the surface area shall be broomed free of dust and loose stones or other foreign matter.

(x) The sand cover seal shall receive on the day of surfacing not less than 15 passes of a pneumatic tyre roller with a minimum weight of 12 tonnes.

2223 REMOVING TREE UNDER BRIDGE

A. Scope

This Clause covers the removal of trees stuck between the piers of bridge/culvert across streams/rivers having small span between piers and passing through forest land. Large trees with branches flowing along with river flow during flood sometimes get stuck between the piers causing outflanking and damage to

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structure and road, if they are not removed in time. Removal of such trees is essential for the safety of bridge/culvert and the road.

B. Method of Removal

Trees stuck between the piers/abutment of bridge/culvert shall be cut into pieces using appropriate tools and removed from the site as soon as practicable.

Ladder or Crane/Girder if available in the bridge shall be used for movement of cutter during cutting operation. Cutting operation and Cut pieces of trees shall be managed carefully with assistance of required manpower for early clearance of blocked water way.

C. Measurement and Payment

Chopping and removal of trees shall be measured in number. Chopping and removal of trees shall be paid as per related contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115.

2224 SERVICE ROAD

A. Scope

This Clause covers the construction of canal service road which may not be less than 3m width. Such service road shall be main or secondary road (number 2 road adjacent to main road / bank of canal at lower elevation) and shall be constructed parallel to canal/main road after cutting humps and filling depressions.

B. Method of Construction

Generally, one bank of the canal is developed as service road for inspection, operation and maintenance of canal. In case of large canals number 2 road is also constructed in addition to main road as alternate service road for uninterrupted operation and maintenance of canal. Canal Service road shall be constructed to be of width not less than 3m in any case. The width of main road which shall be one of the banks of canal shall depend upon the designed geometry of the canal. The top level of the main road shall not be less than the design top level of the canal. However, the top level of the number 2 service road shall be less than the top level of main road. The canal service road (number 2 service road) shall be constructed by cutting the humps and filling the depression on the ground surface. The main canal service road shall be constructed maintaining the required design top level and desired width. Canal service road being the road for operation and maintenance of canal shall not be open for public use. Heavy vehicles shall not be allowed for travelling through such roads.

C. Measurement and Payment

Construction of canal service road of specified width shall be measured in kilometer. Construction of canal service road shall be paid as per related contract unit rate which shall be the full and the final compensation to the Contractor as per Clause 115.

Annex 2200-1

Table: A: Temperature/Volume Corrections for Emulsified Asphalts

Legend: T = observed temperature in degrees Celsius (Fahrenheit) M = multiplier for correcting volumes to the basis of 15.6 ^{o} C (60° F)

*Multiplier (M) for ^{o} C is a close approximation

T ^{o}C	T ^{o}F	M	T ^{o}C	T ^{o}F	M	T ^{o}C	T ^{o}F	M
10	50	1.0025	26.7	80	0.995	43.3	110	0.9875
10.6	51	1.00225	27.2	81	0.99475	43.9	111	0.98725
11.1	52	1.002	27.8	82	0.9945	44.4	112	0.987
11.7	53	1.00175	28.3	83	0.99425	45	113	0.98675
12.2	54	1.0015	28.9	84	0.994	45.6	114	0.9865
12.8	55	1.00125	29.4	85	0.99375	46.1	115	0.98625
13.3	56	1.001	30	86	0.9935	46.7	116	0.986
13.9	57	1.00075	30.6	87	0.99325	47.2	117	0.98575
14.4	58	1.0005	31.1	88	0.993	47.8	118	0.9855
15	59	1.00025	31.7	89	0.99275	48.3	119	0.98525
15.6	60	1.00	32.2	90	0.9925	48.9	120	0.985
16.1	61	0.99975	32.8	91	0.99225	49.4	121	0.98475
16.7	62	0.9995	33.3	92	0.992	50	122	0.9845
17.2	63	0.99925	33.9	93	0.99175	50.6	123	0.98425
17.8	64	0.999	34.4	94	0.9915	51.1	124	0.984
18.3	65	0.99875	35	95	0.99125	51.7	125	0.98375
18.9	66	0.9985	35.6	96	0.991	52.2	126	0.9835
19.4	67	0.99825	36.1	97	0.99075	52.8	127	0.98325
20	68	0.998	36.7	98	0.9905	53.3	128	0.983
20.6	69	0.99775	37.2	99	0.99025	53.9	129	0.98275
21.1	70	0.9975	37.8	100	0.99	54.4	130	0.9825
21.7	71	0.99725	38.3	101	0.98975	55	131	0.98225
22.2	72	0.997	38.9	102	0.9895	55.6	132	0.982
22.8	73	0.99675	39.4	103	0.98925	56.1	133	0.98175
23.3	74	0.9965	40	104	0.989	56.7	134	0.9815
23.9	75	0.99625	40.6	105	0.98875	57.2	135	0.98125
24.4	76	0.996	41.1	106	0.9885	57.8	136	0.981
25	77	0.99575	41.7	107	0.98825	58.3	137	0.98075
25.6	78	0.9955	42.2	108	0.988	58.9	138	0.9805

26.1	79	0.99525	42.8	109	0.98775	59.4	139	0.98025

Annex 1300-1

Table: A: Temperature/Volume Corrections for Emulsified Asphalts

Legend: T = observed temperature in degrees Celsius (Fahrenheit) M = multiplier for correcting volumes to the basis of 15.6 o C (60o F)

*Multiplier (M) for o C is a close approximation

T °C	T °F	M	T °C	T °F	M	T °C	T °F	M
60	140	0.98	68.3	155	0.97625	76.7	170	0.9725
60.6	141	0.97975	68.9	156	0.976	77.2	171	0.97225
61.1	142	0.9795	69.4	157	0.97575	77.8	172	0.972
61.7	143	0.97925	70	158	0.9755	78.3	173	0.97175
62.2	144	0.979	70.6	159	0.97525	78.9	174	0.9715
62.8	145	0.97875	71.1	160	0.975	79.4	175	0.97125
63.3	146	0.9785	71.7	161	0.97475	80	176	0.971
63.9	147	0.97825	72.2	162	0.9745	80.6	177	0.97075
64.4	148	0.978	72.8	163	0.97425	81.1	178	0.9705
65	149	0.97775	73.3	164	0.974	81.7	179	0.97025
65.6	150	0.9775	73.9	165	0.97375	82.2	180	0.97
66.1	151	0.97725	74.4	166	0.9735	82.8	181	0.96975
66.7	152	0.977	75	167	0.97325	83.3	182	0.9695
67.2	153	0.97675	75.6	168	0.973	83.9	183	0.96925
67.8	154	0.9765	76.1	169	0.97275	84.4	184	0.969
						85.0	185	0.96875

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Table: B: Temperature/volume corrections for asphalt materials, For Specific Gravity Above 0.966

Legend: T=Observed temperature in degrees Fahrenheit M=Multiplier for correcting oil volume to the basis of 60ºF

T	M	T	M	T	M	T	M	T	M	T	M
0	1.0211										
1	1.0208	31	1.0102	61	0.9997	91	0.9892	121	0.9788	151	0.9686
2	1.0204	32	1.0098	62	0.9993	92	0.9889	122	0.9785	152	0.9682
3	1.0201	33	1.0095	63	0.999	93	0.9885	123	0.9782	153	0.9679
4	1.0197	34	1.0091	64	0.9986	94	0.9882	124	0.9778	154	0.9675
5	1.0194	35	1.0088	65	0.9983	95	0.9878	125	0.9775	155	0.9672
6	1.019	36	1.0084	66	0.9979	96	0.9875	126	0.9771	156	0.9669
7	1.0186	37	1.0081	67	0.9976	97	0.9871	127	0.9768	157	0.9665
8	1.0183	38	1.0077	68	0.9972	98	0.9868	128	0.9764	158	0.9662
9	1.0179	39	1.0074	69	0.9969	99	0.9864	129	0.9761	159	0.9658
10	1.0176	40	1.007	70	0.9965	100	0.9861	130	0.9758	160	0.9655
11	1.0172	41	1.0067	71	0.9962	101	0.9857	131	0.9754	161	0.9652
12	1.0169	42	1.0063	72	0.9958	102	0.9854	132	0.9751	162	0.9648
13	1.0165	43	1.006	73	0.9955	103	0.9851	133	0.9747	163	0.9645
14	1.0162	44	1.0056	74	0.9951	104	0.9847	134	0.9744	164	0.9641
15	1.0158	45	1.0053	75	0.9948	105	0.9844	135	0.974	165	0.9638
16	1.0155	46	1.0049	76	0.9944	106	0.984	136	0.9737	166	0.9635
17	1.0151	47	1.0046	77	0.9941	107	0.9837	137	0.9734	167	0.9631
18	1.0148	48	1.0042	78	0.9937	108	0.9833	138	0.973	168	0.9628
19	1.0144	49	1.0038	79	0.9934	109	0.983	139	0.9727	169	0.9624
20	1.0141	50	1.0035	80	0.993	110	0.9826	140	0.9723	170	0.9621
21	1.0137	51	1.0031	81	0.9927	111	0.9823	141	0.972	171	0.9618
22	1.0133	52	1.0028	82	0.9923	112	0.9819	142	0.9716	172	0.9614
23	1.013	53	1.0024	83	0.992	113	0.9816	143	0.9713	173	0.9611
24	1.0126	54	1.0021	84	0.9916	114	0.9813	144	0.971	174	0.9607
25	1.0123	55	1.0017	85	0.9913	115	0.9809	145	0.9706	175	0.9604
26	1.0119	56	1.0014	86	0.9909	116	0.9806	146	0.9703	176	0.9601
27	1.0116	57	1.001	87	0.9906	117	0.9802	147	0.9699	177	0.9597
28	1.0112	58	1.0007	88	0.9902	118	0.9799	148	0.9696	178	0.9594
29	1.0109	59	1.0003	89	0.9899	119	0.9795	149	0.9693	179	0.959
30	1.0105	60	1.00	90	0.9896	120	0.9792	150	0.9689	180	0.9587

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Table: B: Temperature/volume corrections for asphalt materials, For Specific Gravity Above 0.966

Legend: T=Observed temperature in degrees Fahrenheit M=Multiplier for correcting oil volume to the basis of 60ºF

T	M	T	M	T	M	T	M	T	M	T	M
181	0.9584	211	0.9483	241	0.9382	271	0.9283	301	0.9184	331	0.9086
182	0.958	212	0.9479	242	0.9379	272	0.9279	302	0.9181	332	0.9083
183	0.9577	213	0.9476	243	0.9375	273	0.9276	303	0.9177	333	0.9079
184	0.9574	214	0.9472	244	0.9372	274	0.9273	304	0.9174	334	0.9076
185	0.957	215	0.9469	245	0.9369	275	0.9269	305	0.9171	335	0.9073
186	0.9567	216	0.9466	246	0.9365	276	0.9266	306	0.9167	336	0.907
187	0.9563	217	0.9462	247	0.9362	277	0.9263	307	0.9164	337	0.9066
188	0.956	218	0.9459	248	0.9359	278	0.9259	308	0.9161	338	0.9063
189	0.9557	219	0.9456	249	0.9356	279	0.9256	309	0.9158	339	0.906
190	0.9553	220	0.9452	250	0.9352	280	0.9253	310	0.9154	340	0.9057
191	0.955	221	0.9449	251	0.9349	281	0.925	311	0.9151	341	0.9053
192	0.9547	222	0.9446	252	0.9346	282	0.9246	312	0.9148	342	0.905
193	0.9543	223	0.9442	253	0.9342	283	0.9243	313	0.9145	343	0.9047
194	0.954	224	0.9439	254	0.9339	284	0.924	314	0.9141	344	0.9044
195	0.9536	225	0.9436	255	0.9336	285	0.9236	315	0.9138	345	0.904
196	0.9533	226	0.9432	256	0.9332	286	0.9233	316	0.9135	346	0.9037
197	0.953	227	0.9429	257	0.9329	287	0.923	317	0.9132	347	0.9034
198	0.9526	228	0.9426	258	0.9326	288	0.9227	318	0.9128	348	0.9031
199	0.9523	229	0.9422	259	0.9322	289	0.9223	319	0.9125	349	0.9028
200	0.952	230	0.9419	260	0.9319	290	0.922	320	0.9122	350	0.9024
201	0.9516	231	0.9416	261	0.9316	291	0.9217	321	0.9118	351	0.9021
202	0.9513	232	0.9412	262	0.9312	292	0.9213	322	0.9115	352	0.9018
203	0.9509	233	0.9409	263	0.9309	293	0.921	323	0.9112	353	0.9015
204	0.9506	234	0.9405	264	0.9306	294	0.9207	324	0.9109	354	0.9011
205	0.9503	235	0.9402	265	0.9302	295	0.9204	325	0.9105	355	0.9008
206	0.9499	236	0.9399	266	0.9299	296	0.92	326	0.9102	356	0.9005
207	0.9496	237	0.9395	267	0.9296	297	0.9197	327	0.9099	357	0.9002
208	0.9493	238	0.9392	268	0.9293	298	0.9194	328	0.9096	358	0.8998
209	0.9489	239	0.9389	269	0.9289	299	0.919	329	0.9092	359	0.8995
210	0.9486	240	0.9385	270	0.9286	300	0.9187	330	0.9089	360	0.8992

Table: B: Temperature/volume corrections for asphalt materials, For Specific Gravity Above 0.966

Legend: T=Observed temperature in degrees Fahrenheit M=Multiplier for correcting oil volume to the basis of 60ºF

T	M	T	M	T	M	T	M	T	M	T	M
361	0.8989	391	0.8892	421	0.8797	451	0.8702	481	0.8608		
362	0.8986	392	0.8889	422	0.8794	452	0.8699	482	0.8605		
363	0.8982	393	0.8886	423	0.8791	453	0.8696	483	0.8602		
364	0.8979	394	0.8883	424	0.8787	454	0.8693	484	0.8599		
365	0.8976	395	0.888	425	0.8784	455	0.869	485	0.8596		
366	0.8973	396	0.8876	426	0.8781	456	0.8687	486	0.8593		
367	0.8969	397	0.8873	427	0.8778	457	0.8683	487	0.859		
368	0.8966	398	0.887	428	0.8775	458	0.868	488	0.8587		
369	0.8963	399	0.8867	429	0.8772	459	0.8677	489	0.8583		
370	0.896	400	0.8864	430	0.8768	460	0.8674	490	0.858		
371	0.8957	401	0.8861	431	0.8765	461	0.8671	491	0.8577		
372	0.8953	402	0.8857	432	0.8762	462	0.8668	492	0.8574		
373	0.895	403	0.8854	433	0.8759	463	0.8665	493	0.8571		
374	0.8947	404	0.8851	434	0.8756	464	0.8661	494	0.8568		
375	0.8944	405	0.8848	435	0.8753	465	0.8658	495	0.8565		
376	0.8941	406	0.8845	436	0.8749	466	0.8655	496	0.8562		
377	0.8937	407	0.8841	437	0.8746	467	0.8652	497	0.8559		
378	0.8934	408	0.8838	438	0.8743	468	0.8649	498	0.8556		
379	0.8931	409	0.8835	439	0.874	469	0.8646	499	0.8552		
380	0.8928	410	0.8832	440	0.8737	470	0.8643				
381	0.8924	411	0.8829	441	0.8734	471	0.864				
382	0.8921	412	0.8826	442	0.8731	472	0.8636				
383	0.8918	413	0.8822	443	0.8727	473	0.8633				
384	0.8915	414	0.8819	444	0.8724	474	0.863				
385	0.8912	415	0.8816	445	0.8721	475	0.8627				
386	0.8908	416	0.8813	446	0.8718	476	0.8624				
387	0.8905	417	0.881	447	0.8715	477	0.8621				
388	0.8902	418	0.8806	448	0.8712	478	0.8618				
389	0.8899	419	0.8803	449	0.8709	479	0.8615				
390	0.8896	420	0.88	450	0.8705	480	0.8611				

Table :C :Temperature/volume corrections for asphalt materials, For specific gravity above 0.850 to 0.966

Legend: T=Observed temperature in degrees Fahrenheit M=Multiplier for correcting oil volume to the basis of 60ºF

T	M	T	M	T	M	T	M	T	M	T	M
0	1.0241										
1	1.0237	31	1.0116	61	0.9996	91	0.9877	121	0.976	151	0.9643
2	1.0233	32	1.0112	62	0.9992	92	0.9873	122	0.9756	152	0.9639
3	1.0229	33	1.0108	63	0.9988	93	0.9869	123	0.9752	153	0.9635
4	1.0225	34	1.0104	64	0.9984	94	0.9865	124	0.9748	154	0.9632
5	1.0221	35	1.01	65	0.998	95	0.9861	125	0.9744	155	0.9628
6	1.0217	36	1.0096	66	0.9976	96	0.9857	126	0.974	156	0.9624
7	1.0213	37	1.0092	67	0.9972	97	0.9854	127	0.9736	157	0.962
8	1.0209	38	1.0088	68	0.9968	98	0.985	128	0.9732	158	0.9616
9	1.0205	39	1.0084	69	0.9964	99	0.9846	129	0.9728	159	0.9612
10	1.0201	40	1.008	70	0.996	100	0.9842	130	0.9725	160	0.9609
11	1.0197	41	1.0076	71	0.9956	101	0.9838	131	0.9721	161	0.9605
12	1.0193	42	1.0072	72	0.9952	102	0.9834	132	0.9717	162	0.9601
13	1.0189	43	1.0068	73	0.9948	103	0.983	133	0.9713	163	0.9597
14	1.0185	44	1.0064	74	0.9944	104	0.9826	134	0.9709	164	0.9593
15	1.0181	45	1.006	75	0.994	105	0.9822	135	0.9705	165	0.9589
16	1.0177	46	1.0056	76	0.9936	106	0.9818	136	0.9701	166	0.9585
17	1.0173	47	1.0052	77	0.9932	107	0.9814	137	0.9697	167	0.9582
18	1.0168	48	1.0048	78	0.9929	108	0.981	138	0.9693	168	0.9578
19	1.0164	49	1.0044	79	0.9925	109	0.9806	139	0.969	169	0.9574
20	1.016	50	1.004	80	0.9921	110	0.9803	140	0.9686	170	0.957
21	1.0156	51	1.0036	81	0.9917	111	0.9799	141	0.9682	171	0.9566
22	1.0152	52	1.0032	82	0.9913	112	0.9795	142	0.9678	172	0.9562
23	1.0148	53	1.0028	83	0.9909	113	0.9791	143	0.9674	173	0.9559
24	1.0144	54	1.0024	84	0.9905	114	0.9787	144	0.967	174	0.9555
25	1.014	55	1.002	85	0.9901	115	0.9783	145	0.9666	175	0.9551
26	1.0136	56	1.0016	86	0.9897	116	0.9779	146	0.9662	176	0.9547
27	1.0132	57	1.0012	87	0.9893	117	0.9775	147	0.9659	177	0.9543
28	1.0128	58	1.0008	88	0.9889	118	0.9771	148	0.9655	178	0.9539
29	1.0124	59	1.0004	89	0.9885	119	0.9767	149	0.9651	179	0.9536
30	1.012	60	1.00	90	0.9881	120	0.9763	150	0.9647	180	0.9532

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Table: C: Temperature/volume corrections for asphalt materials, For specific gravity above 0.850 to 0.966

Legend: T=Observed temperature in degrees Fahrenheit M=Multiplier for correcting oil volume to the basis of 60ºF

T	M	T	M	T	M	T	M	T	M	T	M
181	0.9528	211	0.9414	241	0.9301	271	0.919	301	0.908	331	0.8971
182	0.9524	212	0.941	242	0.9298	272	0.9186	302	0.9076	332	0.8967
183	0.952	213	0.9407	243	0.9294	273	0.9182	303	0.9072	333	0.8963
184	0.9517	214	0.9403	244	0.929	274	0.9179	304	0.9069	334	0.896
185	0.9513	215	0.9399	245	0.9286	275	0.9175	305	0.9065	335	0.8956
186	0.9509	216	0.9395	246	0.9283	276	0.9171	306	0.9061	336	0.8952
187	0.9505	217	0.9391	247	0.9279	277	0.9168	307	0.9058	337	0.8949
188	0.9501	218	0.9388	248	0.9275	278	0.9164	308	0.9054	338	0.8945
189	0.9498	219	0.9384	249	0.9272	279	0.916	309	0.905	339	0.8942
190	0.9494	220	0.938	250	0.9268	280	0.9157	310	0.9047	340	0.8938
191	0.949	221	0.9376	251	0.9264	281	0.9153	311	0.9043	341	0.8934
192	0.9486	222	0.9373	252	0.926	282	0.9149	312	0.9039	342	0.8931
193	0.9482	223	0.9369	253	0.9257	283	0.9146	313	0.9036	343	0.8927
194	0.9478	224	0.9365	254	0.9253	284	0.9142	314	0.9032	344	0.8924
195	0.9475	225	0.9361	255	0.9249	285	0.9138	315	0.9029	345	0.892
196	0.9471	226	0.9358	256	0.9245	286	0.9135	316	0.9025	346	0.8916
197	0.9467	227	0.9354	257	0.9242	287	0.9131	317	0.9021	347	0.8913
198	0.9463	228	0.935	258	0.9238	288	0.9127	318	0.9018	348	0.8909
199	0.946	229	0.9346	259	0.9234	289	0.9124	319	0.9014	349	0.8906
200	0.9456	230	0.9343	260	0.9231	290	0.912	320	0.901	350	0.8902
201	0.9452	231	0.9339	261	0.9227	291	0.9116	321	0.9007	351	0.8899
202	0.9448	232	0.9335	262	0.9223	292	0.9113	322	0.9003	352	0.8895
203	0.9444	233	0.9331	263	0.9219	293	0.9109	323	0.9	353	0.8891
204	0.9441	234	0.9328	264	0.9216	294	0.9105	324	0.8996	354	0.8888
205	0.9437	235	0.9324	265	0.9212	295	0.9102	325	0.8992	355	0.8884
206	0.9433	236	0.932	266	0.9208	296	0.9098	326	0.8989	356	0.8881
207	0.9429	237	0.9316	267	0.9205	297	0.9094	327	0.8985	357	0.8877
208	0.9425	238	0.9313	268	0.9201	298	0.9091	328	0.8981	358	0.8873
209	0.9422	239	0.9309	269	0.9197	299	0.9087	329	0.8978	359	0.887
210	0.9418	240	0.9305	270	0.9194	300	0.9083	330	0.8974	360	0.8866

Table: C :Temperature/volume corrections for asphalt materials, For specific gravity above 0.850 to 0.966

Legend: T=Observed temperature in degrees Fahrenheit M=Multiplier for correcting oil volume to the basis of 60ºF

T	M	T	M	T	M	T	M	T	M	T	M
361	0.8863	391	0.8756	421	0.8651	451	0.8547	481	0.8444		
362	0.8859	392	0.8753	422	0.8647	452	0.8543	482	0.844		
363	0.8856	393	0.8749	423	0.8644	453	0.854	483	0.8437		
364	0.8852	394	0.8746	424	0.864	454	0.8536	484	0.8433		
365	0.8848	395	0.8742	425	0.8637	455	0.8533	485	0.843		
366	0.8845	396	0.8738	426	0.8633	456	0.8529	486	0.8427		
367	0.8841	397	0.8735	427	0.863	457	0.8526	487	0.8423		
368	0.8838	398	0.8731	428	0.8626	458	0.8522	488	0.842		
369	0.8834	399	0.8728	429	0.8623	459	0.8519	489	0.8416		
370	0.8831	400	0.8724	430	0.8619	460	0.8516	490	0.8413		
371	0.8827	401	0.8721	431	0.8616	461	0.8512	491	0.841		
372	0.8823	402	0.8717	432	0.8612	462	0.8509	492	0.8406		
373	0.882	403	0.8714	433	0.8609	463	0.8505	493	0.8403		
374	0.8816	404	0.871	434	0.8605	464	0.8502	494	0.8399		
375	0.8813	405	0.8707	435	0.8602	465	0.8498	495	0.8396		
376	0.8809	406	0.8703	436	0.8599	466	0.8495	496	0.8393		
377	0.8806	407	0.87	437	0.8595	467	0.8492	497	0.8389		
378	0.8802	408	0.8696	438	0.8592	468	0.8488	498	0.8386		
379	0.8799	409	0.8693	439	0.8588	469	0.8485	499	0.8383		
380	0.8795	410	0.8689	440	0.8585	470	0.8481				
381	0.8792	411	0.8686	441	0.8581	471	0.8478				
382	0.8788	412	0.8682	442	0.8578	472	0.8474				
383	0.8784	413	0.8679	443	0.8574	473	0.8471				
384	0.8781	414	0.8675	444	0.8571	474	0.8468				
385	0.8777	415	0.8672	445	0.8567	475	0.8464				
386	0.8774	416	0.8668	446	0.8564	476	0.8461				
387	0.877	417	0.8665	447	0.856	477	0.8457				
388	0.8767	418	0.8661	448	0.8557	478	0.8454				
389	0.8763	419	0.8658	449	0.8554	479	0.8451				
390	0.876	420	0.8654	450	0.855	480	0.8447				

Annex 2200-2

Properties of WMA to be verified Based in Accordance with Testing Procedure as per AASHTO/ ASTM Standards

i) Coating – (AASHTO T 195/ ASTM D 2489)

ii) Compactibility – (AASHTO T 245/ ASTM D 1559

iii) Moisture Sensitivity – (AASHTO T 283 / ASTM D 1075)

AASHTO T 195/ ASTM D2489

The standard method of test for : Determining degree of particle coating of Asphalt Mixture" helps in determining the particle coating in asphalt mix based on the percentage of fully coated aggregate present in a mix. The specification also helps in determining the mixing time required for satisfactory coating of aggregate in the asphalt mixture.

After producing WMA mix by lowering the temperature by at least 30^0 C lower than conventional hot-mix, samples of the mix are taken immediately after discharge from the pugmill. Coating is only measured on aggregate retained on 9.5 mm sieve. So the material is sieved on a 9.5 mm sieve while still hot and roughly 200 – 500 gram of sieved sample is collected.

The percentage of coated particle is determined by;

$$\% \text{ of Coating} = \frac{\text{No. of completely coated particles}}{\text{Total No. of particles}} \times 100\%$$

At least 95 percent of the coarse aggregate particles shall be fully coated at a temperature at least 30^0 C lower than conventional hot – mix

AASHTO T245/ASTM D 1559

The standard method of test for “Resistance to plastic flow for bituminous mixture using Marshal Apparatus" covers the measurement of resistance to plastic flow of cylindrical bituminous mixture samples by the means of a Marshal Apparatus.

This test method is specified to verify that the warm – mix samples attain equivalent resistance to plastic deformation relative to conventional mixes at temperatures at least 30^0 C lower than conventional hot-mix. The specification details the procedure for preparing a cylindrical bituminous mixture samples of 100 mm diameter consisting of around 1200 g of material. The sample is prepared by compacting using a standard Marshal Hammer. The samples are checked for Marshal Stability and flow under constant displacement rate testing using a Marshal Apparatus after being immersed in water at 60 ±10 C for 30 to 40 minutes.

WMA mixes shall have at least 9 KN Marshal Stability value (12 KN if sample prepared with PMB) and flow between 3 to 6 mm.

AASHTO T283/ASTM D 1075

The standard method for " Resistance of compacted asphalt mixture samples to moisture induced damage" covers preparation of specimen and the measurement of the change of diametrical tensile strength resulting from the effect of water saturation and accelerated water conditioning, with a freeze-thaw cycle, of compacted asphalt mixtures. The results may be used to predict long- term stripping susceptibility of the asphalt mixtures and evaluate liquid anti- stripping additives that are added to the asphalt binder.

The test is performed by compacting cylindrical bituminous mixture specimens to an air void level of six to eight percentages. Three specimens are selected as a control and tested without moisture conditioning, and three specimens are selected to be conditioned by saturating with water undergoing a freeze cycle (-180 C for at least 16 hours), and subsequently having 60 ± 10 C water soaking cycle for 24 hours. The

specimens are then transferred to a 25 ± 10 C water bath for two hours and then tested for indirect tensile strength by loading the specimens at a constant rate and measuring the peak force required to break the specimen. the tensile strength of the conditioned specimens is compared to the control specimens to determine the Tensile Strength Ratio (TSR)

$$TSR\ \% = \frac{\text{Tensile strength of conditioned samples}}{\text{Tensile strength of unconditioned samples}} \times 100$$

The Tensile Strength Ration (TSR) of the hot- mix and the warm – mix shall be determined as per the AASHTO T 283. A TSR of above 80 percent for the warm–mix that is prepared at least 300 C below corresponding hot-mix will ensure sufficient resistance against moisture susceptibility.

SECTION 2300: ELECTRIC LINE AND ELECTRIFICATION WORKS

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Government of Nepal
Ministry of Energy, Water Resources and Irrigation
Department of Water Resources and Irrigation
Jawalakhel, Lalitpur

2301 SCOPE

This Section cover the general requirements for works related to the electric line works such as erecting steel, timber and PSC pole, fixing ACSR conductor, distribution transformer and installing stay set for HT and LT line. This section also covers the electrification works such as fixing main switch, busbar strips, distribution boards, lights, fans, sockets, streetlight poles, Earthing and Wiring.

2302 ERECTING STEEL ELECTRIC POLES

(1) General

This section covers the general requirements towards design, manufacture, testing at manufacturer's works, supply and delivery for tubular steel poles of circular cross section for overhead lines.

(2) Materials

The tubular steel poles shall conform to the latest edition of Indian Standard specification IS: 2713 (Part – I, III): 1980 where specified otherwise in this specification. The materials shall be suitable for operation in tropical climate and shall be able to withstand wide range of temperature variation.

The materials used in construction of tubular steel poles shall be of the tested quality of steels of minimum tensile strength 540 Mpa. The materials, when analyzed in accordance with IS: 228 (Part-III: 1972) and IS: 228 (Part-IX) shall not show Sulphur and phosphorous contents of more than 0.060 percent each.

The tubes for making poles shall conform to grade YSt 240 or YSt 310 of IS: 1161-2014 as appropriate, except that manual metal arc welding process may also be used to make the tubes.

Poles shall be well-finished, clean and free from harmful surface defects. Ends of the poles shall be cut square. Poles shall be straight, smooth and cylindrical.

When the tubes are made by manual metal arc welding, the welded joints shall be of good quality, free from scale, surface defects, cracks, etc.

(3) Tolerances

The poles shall be as nearly circular as possible, and their outside diameters shall not vary from the appropriate value, except at the joint or step, by more than ± 1 percent.

In the case of welded tubes, its thickness shall not fall below the thickness specified by more than 10 percent and in case of seamless tubes, its thickness shall not fall below the thickness specified by more than 12% or 15% (as per ratio of thickness to outside diameter).

The tolerance on the length shall be as follows:

- On the length of any section ±40 mm
- On the overall length of pole ±25 mm

The mean weight for bulk supplies shall be not more than 5 % below the calculated value. The weight of any single pole shall not fall below the calculated weight by more than 7·5 %.

The finished pole shall not be out of straightness by more than 1/600 of its length.

(4) Selection of Poles

For the selection of poles, tensile test and chemical analysis for Sulphur and phosphorus, Deflection test, Permanent set test and Drop test shall be done as per IS 2713 (Part 1) - 1980.

(5) Protection from Corrosion

Unless otherwise specified, the poles shall be coated with black bituminous paint conforming to IS: 158-2015 throughout, internally and externally, up to the level which goes inside the earth. The remaining portion of the exterior shall be painted with one coat of red oxide primer as specified in IS: 2074-1979.

Alternatively, tubular poles (over the entire length or only certain sections) may be galvanized.

(6) Earthing

If earthing arrangements are required by the purchaser, a through hole of 14 mm diameter shall be provided in each pole at a height of 300 mm above the planting depth.

(7) Measurement

Erecting steel pole and applying bitumen lining shall be measured in numbers as per Drawing.

(8) Payment

Erecting steel pole and applying bitumen lining measured as above, shall be paid at the contract unit rate. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

2303 ERECTING WOODEN TREATED POLES

(1) General

This section covers wooden treated poles made of different species of timber and suitable for carrying overhead electric power transmission lines and telephone circuit and also covers the methods of testing of wooden poles, required for determining the suitability of full-length wood poles.

(2) Materials

The wood poles shall be classified in seven classes based on strength and are categorized into three groups based on the modulus of rupture as per IS 876:1992 and following test methods described as per IS 1708:1986 and IS 1900:1974.

Wooden poles butts shall be sawn square, and bark shall be completely removed, and all the branches shall be dressed down flush with the stem. The tops shall be levelled in the shape of an inverted ‘V’ for length equal to top diameter or 100 mm whichever is less.

(3) Preliminary and Preservative Treatment

Preliminary Treatment

Poles prepared as in 2303 (2) above shall be given as soon as possible, a prophylactic treatment specified in IS 401: 2001 to prevent insect attack and fungal damage. The treated poles shall be stacked on creosoted or otherwise treated crossers at least 150 mm clear off the ground, until they are sufficiently seasoned and ready for preservative treatment. The ground under and around the stacks shall be properly drained and kept free from wood shavings, bark and other wood refuse.

Preservative Treatment

The poles shall be treated with a preservative so as to impregnate completely the sapwood and as much of heartwood of non-durable species (IS 876:1992-Annex A) as possible. The pressure and the preservative treatment shall be as given in IS 401: 2001.

Remedial Treatment

The remedial treatment shall be carried out only of those poles which are not recommended to be rejected by for excessive rot, insect attack, or mechanical damage. The suitable remedial treatment for the biological and/or mechanical damage shall be given according to IS 6711:1972 when fungus growth and/or insect attack or any other defects are noticed on the pole surface on inspection or when the initial treatment is not considered sufficiently resistant.

Replacement of pole

The pole shall be replaced by a treated solid or jointed wood pole when the damage due to decay or development of defects is beyond the safe limit or when any permissible defect extends to 2.5 times its original dimensions. The new pole shall be erected with a distance of 1 m from the position of the original pole.

(4) Tolerances

The length shall be measured between the extreme ends of poles. Poles shall be not more than 50 mm shorter or more than 100 mm longer than the specified length. Circumference and curvature of pole shall be measured as per table 1 and figure 1 of IS 876:1992.

Poles shall be reasonably straight and curvature shall be allowed subject to limitation as per 10.3.10 of IS 876:1992. Only one short crook in a pole is permissible provided the inclination is not more than the diameter of the crooked section of the pole and the same is classified one class lower.

(5) Defects

The measurement of defect shall be done as given in IS 3364 (Part 1):2000. The following defects shall be totally prohibited: Decay, Hollows in the top, Cross breaks, and large holes.

As per IS 876:1992, the following defects shall be permitted to a limited extent: Splits, Checks, Hollow heart, Rot, Ring shake, Grain, Insect damages, Knots and Scars.

(6) Measurement

Erecting wooden treated pole including excavation and placing of footing, ramming and backfilling shall be measured in numbers as per Drawing.

(7) Payment

Erecting wooden treated pole measured as above, shall be paid at the contract unit rate. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

2304 ERECTING PRESTRESSED CONCRETE (PSC) POLES

(1) General

This section covers prestressed concrete poles suitable for use in overhead power, traction and telecommunication lines.

(2) Materials

The prestressed cement concrete poles shall conform to IS: 7321-1974, IS: 1678-1998 and IS: 2905-1989. The poles are free from cracks visible to the naked eye, honey combing and are of good finish.

a) Cement

The cement used in the manufacture of prestressed concrete poles shall be any of the following:

i. Portland slag cement conforming to IS 455 but with not more than 50 percent slag content,

ii. Rapid hardening Portland cement conforming to IS 8041,

iii. 43 grade ordinary Portland cement conforming to IS 269:2015.

iv. 53 grade ordinary Portland cement conforming to IS 269:2015.

b) Aggregates

Aggregates used for the manufacture of prestressed concrete poles shall conform to IS 383. Where specified, a sample of the aggregate shall be submitted by the manufacturer to the purchaser for approval.

c) Prestressing Steel

The prestressing steel shall be any one of the following:

a) Plain hard drawn steel wire conforming to either IS 1785 (Part 1) or IS 1785 (Part 2),

b) Cold drawn indented wire conforming to IS 6003,

c) Uncoated stress relieved strand conforming to IS 6006 or IS 14268,

d) High tensile steel bar conforming to IS 2090.

All prestressing steel shall be free from splits, harmful scratches, surface flaws, rough, aged and imperfect edges and other defects likely to impair its use in prestressed concrete. Slight rust may be permitted provided there is no surface pitting visible to the naked eye.

d) Reinforcement

Reinforcing bars and wires shall conform to IS 432 (Part 1) or IS 432 (Part 2) or IS 1786, as the case may be.

All reinforcement shall be free from loose scale, rust and coats of paint, oil, grease, clay or other material that may have deteriorating effect on the bond between the reinforcement and the concrete. Slight rust may be permitted provided there is no surface pitting visible to the naked eye.

e) Concrete

The grade of concrete shall be not less than M 40.

f) Admixture

Admixture may be used with the approval of the purchaser. However, any admixture containing chlorides in any form shall not be used. The admixture shall conform to IS 9103.

(3) Design

The design considerations shall comply to IS 1678:1998. The poles shall be so designed that they do not fail owing to failure initiated by compression in concrete and its strength in transverse direction shall be sufficient to take the load due to wind on wires and poles, multiplied by load factor. Where specifically stated, snow load shall also be taken into consideration. Wind pressure may also be determined as specified in IS 875.

The strength of the pole in the direction of the line shall not be less than one-quarter of the strength required in the transverse direction. The load factor on transverse strength for prestressed concrete poles shall not be less than 2.5. This factor may be reduced to a value not less than 2.0 in the case of power transmission lines.

The permissible design stress for high tensile steel and for concrete in compression under the average permanent load shall be in accordance with IS 1343. The permissible design flexural tensile stress for concrete under average permanent load may be taken as 3.0 N/mm^2.

Poles intended to be fitted with stays or supported by struts shall be designed accordingly, and shall be appropriately tested. Method of selection of prestressed concrete pole in any given situation shall be as specified in IS: 7321.

The minimum depth of planting of a pole below ground level shall be in accordance with Table 23.1, the actual depth being determined on the basis of ground condition.

Table 23.1 Minimum Depth of Planting of Reinforced Concrete Poles in the Ground

Length of Pole (m)	Minimum Depth of Planting in Ground (m)
6.0 to 7.0	1.20
7.5 to 9.0	1.50
9.5 to 11.0	1.80
11.5 to 13.0	2.00
13.5 to 14.5	2.20
15.0 to 16.5	2.30

17.0	2.40

The manufacture of the pre stressed concrete poles shall follow the IS 1678:1998 or equivalent specifications. Earthing shall be provided during manufacturing process following the IS 1678:1998 or equivalent specifications. During manufacture, sufficient number of holes shall be provided in the poles for the attachment of cross arms and other equipment.

During manufacture, tests on concrete shall be carried out as detailed in IS 1678. The transverse strength test on poles shall be conducted in accordance with IS 2905.

(4) Dimension and Tolerances

The minimum overall length of poles shall be 6 m and subsequent length shall be in steps of 0.5 m. The length of poles shall be determined depending upon the type of line, that is power transmission (high voltage) or power distribution (low voltage) lines, required clearance of conductors from ground level, expected sag (which depends upon spacing of poles and allowable tension in conductor), position of cross-arms and the planting depth.

The tolerances for prestressed concrete poles shall be as under:

- Overall length of poles ±15 mm
- Cross-sectional dimension ±5 mm
- Uprightness or straightness 0.5 percent

For measurement of uprightness of straightness of prestressed concrete pole, the procedure given in 4.2.1.1 of IS 1678:1998 or any other satisfactory method shall be followed.

(5) Handling

Prestressed concrete poles are heavy items and their resistance to impact is low in comparison to that of metal poles. Sufficient care shall be taken in handling and transport of these poles.

The poles shall preferably be handled with major axis in horizontal position. The handling and lifting conditions shall be considered in design and indicated on the pole unless otherwise specified by the designer, poles shall be lifted from at least two points, one point being roughly at a distance of 1/5th of length from bottom, and the other at a distance of 1/4th of length from top. Poles having self-weight more than 500 kg shall preferably be lifted at four points, the position of point of lift shall be 1/6th of length and 1/3rd of length from bottom and 2/5th of length and 1/5th of length from top. This system shall be followed both for mechanical and manual loading.

Single point lifting through the mid length of the pole shall be avoided since this may cause concentration of stresses in only that particular section, thus producing cracks. In case of manual handling, the pole may be uniformly supported all over its lengths and not at its ends.

(6) Loading, Unloading and Transportation

Poles shall preferably be loaded and unloaded by means of crane or other similar mechanical device. If mechanical loading and unloading is not practicable or economical, manual loading and unloading may be done, according to the procedure described in 4.4 of IS 7321:1974.

While poles are to be loaded into truck, wagon, trailer, etc, either wooden sleepers or steel rails of sufficient length shall be put in a gentle slope against body of the vehicle at 3 or 4 places. Similar procedure shall be followed for unloading of the poles. It is desirable to put some sand filled sacks or similar material at ground level in front of slanting sleepers/rails, so that after sliding down, the poles may sit on sand cushion without appreciable impact.

While loading and unloading, care shall be taken to avoid dropping, dropping with a jerk or striking of the poles against each other. Poles may be stacked in body of vehicle in multiple layers. Two uniform sized wooden battens of suitable cross section shall be put in -between the layers of poles running across the length of the poles.

The poles may be transported either by 8 wheeler wagons or trucks or trailers depending upon distance and convenience. While transporting, the poles shall preferably be placed parallel to the direction of haulage and with major axis in horizontal position. All the poles shall be tightly secured to the body of the vehicle.

(7) Erection of Poles

Concrete poles shall be erected and positioned in such a way that the major axis is perpendicular with the direction of the power line. Jerking and swinging of poles caused by sudden lifting as well as striking of the poles with ground or other objects shall be avoided. The poles shall be buried in the ground at least up to the distance of minimum specified planting depth from bottom according to Table 23.1 or equivalent.

Foundation pit may be cut with suitable equipment such as earth auger. The size of the pit will depend upon the size of base plate required to be put under the pole and space required for working.

For prestressed concrete poles, a concrete base plate shall be provided at the bottom of trench, size of which will depend upon bearing capacity of soil. In normal soil condition, the size of concrete base plate shall be 450 x 450 x 75 mm. Alternatively, with the approval of the engineer in-charge, one or two baulks of reinforced cement concrete or timber of size 800 X 300 X 100 mm may be provided. If the soil is non-cohesive, concreting shall be done right from bottom up to 150 mm above the planting depth to safeguard from overturning moments. The details of preparing foundations and erection are given in IS: 5613 (Part I/Section 2)-1971. The concrete poles are generally erected by direct pole method.

Stays shall be provided wherever necessary before the conductors are given their working tension. Concrete base block and foundation concrete as required shall be prepared, cast and cured, as per IS: 456-2000. Back fill of trench shall be well compacted. After first monsoon, the foundation shall be inspected and back filled if necessary. Stringing of the conductors shall be done as soon as foundation concrete has been cured and hardened and soil has been well compacted.

(8) Measurement

Erecting PSC pole including excavation and placing of footing, ramming and backfilling shall be measured in numbers as per Drawing or as specified in the contract.

(9) Payment

Erecting PSC pole measured as above, shall be paid at the contract unit rate. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

2305 ACSR CONDUCTOR

(1) General

This specification provides requirements for the Aluminium Conductors with Steel Reinforced (ACSR) used for overhead power transmission and distribution line purposes.

(2) Material

The conductor shall be constructed of hard-drawn aluminium and galvanized steel wires which have the mechanical and electrical properties specified in Tables 1 and 2 of IS 398 (Part 2):1996. The EC grade aluminium rods for use in the manufacture of aluminium wires shall conform to IS 5484: 1978. The coating of the galvanized steel wires shall be applied by the hot process or electrolysis process in accordance with IS: 4826–2023. The wires used for standard conductor shall be smooth and free from imperfections, such as spills and splits.

The aluminium and galvanized steel wires for the standard constructions covered by this standard shall have the diameter specified in Tables 1 and 2 of IS 398 (Part 2):1996. The diameter of the galvanized steel wire shall be measured over the zinc coating.

The steel core and the first layer of aluminum shall be greased. The grease shall be of neutral type and at

a temperature of 100º C and the grease neither flow nor extrude from the conductor. The grease shall retain its properties as resistance to oxidation and chemical stability at all service temperatures. The steel strands of ACSR conductor shall be performed so that they remain inert and do not move relative to each other when the conductor is out.

The outermost layer of all conductors shall be stranded with right hand lay. The correct tension must be maintained on the stranding machine when spinning the cable to avoid the possibility of bird caging during stringing. Any condition not complying may be rejected at the discretion of the Engineer. The ACSR conductors must be manufactured by a company approved to quality standard ISO 9001 or ISO 9002. The ISO certification number, the name of the authorized approving authority with the contact address and telephone and fax numbers shall also be stated. The Bidder shall enclose a verified copy of the ISO certificate with the bid.

The purity of the Aluminum shall be the highest commercially available and not less than

99.5%, the copper content not exceeding 0.48%. The contractor shall submit the certificates of analysis giving the percentage and the nature of any impurities in the metal from which the wires are made. Aluminum wire shall be made to BS2627 and steel wires to BS4565.

(3) Joints In Wire

The wires shall be drawn in continuous length, without joints, except those made in wire rod or before drawing operation. No two joints shall occur in the aluminium wires closer than 15 meters. No joints shall be permitted in galvanized steel wire unless the core consists of seven or more steel wires. In the later case, joints in individual wires are permitted, but no two such adjacent joints shall be less than 15 meters.

During stranding in aluminium wire no welds shall be made for the purpose of achieving the required conductor length. Joints shall be dressed smoothly with a diameter equal to that of parent wires and shall not be kinked. The jointing process and test shall comply with IS 398 (Part 2): 1996.

No joints of any kind shall be made in the finished coated steel wires.

(4) Stranding and Lay Ratio

The wires used in manufacturing of stranded conductors shall satisfy all requirements of IS: 398/ 1996 (Part-I & II) before stranding. For ACSR, the lay ratio (Ratio of the aerial length of a complete turn of the helix formed by an individual wire in a stranded conductor to the external diameter of the helix) of the different layers shall be within the limit given under Table No. 4 of IS: 398 Part 2. In all constructions, the successive layers shall have opposite directions of lay and the outer most layers being right handed. The wires in each layer shall be evenly and closely stranded. In conductor having multiple layers of aluminium wires, the lay ratio of any aluminium layers shall be not greater than the lay ratio of the aluminium layer immediately beneath it.

Steel wires shall be formed during stranding so that they remain intact when conductor is cut for jointing operation.

(5) Standard Length

Minimum length of ACSR Squirrel & ACSR Weasel Conductors should be 2(two) km. & in case of ACSR Rabbit, DOG and Wolf, it should be 1(one) Km. Longer lengths are also acceptable provided they are within gross weight limit. The conductor shall be supplied in standard lengths of not less than 95% of the total quantity. The quantity of the conductor in lengths shorter than standard ones shall not exceed 5% of the total quantity to be supplied.

Further, single conductor length in respect of such 5 % (maximum) shall be supplied in random length of not less than 50% of the standard length and shall be supplied in individual drum. Such random length shall be acceptable to the maximum extent of 5% of the offered quantity.

(6) Gross Weight

The gross weight of each wooden drum containing conductor of all sizes shall not exceed 900 kg with a

tolerance limit of ±10 %. Drums containing conductor having gross weight above 990 kg will not be accepted in any case. Also more than two lengths in one conductor drum will not be accepted.

(7) Tolerances

The following tolerances shall be permitted:

i. Tolerance on nominal diameter of aluminium wires: ±1 (one) percent.

ii. Tolerance on nominal diameter of galvanized steel wires: ±2 (two) percent.

Unless otherwise agreed to between the purchaser and the manufacturer, galvanized steel reinforced aluminium conductor shall be supplied in the manufacturer's usual production lengths and with a permuted variation of ±5 percent in the length of anyone conductor length.

(8) Tests

The conductors shall be subjected to routine and acceptance test in accordance with the IS 398:1996 (Part 2).

(9) Measurement

Fixing ACSR conductor of various sizes and lengths shall be measured in numbers as per Drawing or as specified in the contract.

(10) Payment

Fixing ACSR conductor of various sizes and lengths measured as above, shall be paid at the contract unit rate. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

2306 DISTRIBUTION TRANSFORMER

(1) General

This specification provides design, manufacturing, testing, supply, delivery, and performance requirements of three phase distribution transformers of different capacities with accessories including earthing set. The equipment supplied under this specification must strictly comply with the latest standards and guidelines laid out by the Nepal Electricity Authority (NEA). These units are intended for outdoor use in the distribution networks across various climatic zones of Nepal.

(2) System and Environmental Conditions

- Location: Nepal distribution grid (including the Terai plains, mid-hills, and high-altitude mountainous sub-stations).
- Standard Ambient Temperature: Maximum 45°C, minimum -5°C, with a design monthly average of 35°C.
- Altitude: Suitable for installation up to 1,000 meters above sea level without derating. De-rating factors apply for high-altitude installations in northern districts.
- Relative Humidity: Up to 100% saturation during the monsoon season.

(3) Core & Winding Material Requirements

- **Core:** High-grade, non-aging **Cold Rolled Grain Oriented (CRGO)** silicon steel laminations. Cut-type cores are explicitly forbidden under NEA procurement standards.
- **Windings:** Electrolytic grade copper with paper insulation or double-paper covering. Aluminum windings are strictly prohibited for distribution transformers deployed in the NEA network.
- **Insulating Oil:** New, uninhibited mineral insulating oil completely free of PCBs, strictly complying with **IS:335** or **IEC 60296**.

(4) Electrical and Rating Specifications

- **Standard Capacities (kVA): 25, 50, 100, 150, and 200 kVA** for standard pole-mounted layouts.
- **Voltage Ratio:** Primary **11 kV** (nominal network voltage) or 33 kV; Secondary **400/230V or 415/240V** under no-load conditions.
- **Frequency:** 50 Hz standard system frequency.
- **Vector Group: Dyn11** configuration (Delta connected primary, Star connected secondary with an externally accessible neutral bushing).
- **Tap Changer:** Off-circuit manually operated tap-changing switch on the HV winding providing tap steps of **±2.5% and ±5%**.

(5) System Earthing & Accessories Set (All Complete)

Every installation requires a complete component kit designed for stable system protection and pole deployment:

- **Lightning Arresters (L.A.):** Heavy-duty, gapless Zinc Oxide (ZnO) surge arresters rated at 9 kV or 12 kV for 11 kV grids, connected directly to the high-voltage side structure.
- **D.O. Fuse (Drop Out Fuse):** Expulsion type dropout fuse assembly containing proper element sizes relative to the transformer's kVA rating to insulate localized overload faults.
- **G.O. Switch (Gang Operated Switch):** Air-break, triple-pole isolation handle enabling operations crew to de-energize the entire H-pole structure safely.
- **Earthing Configuration:** Complete earthing installation utilizing a minimum of **three separate earth pits** driven into the ground spaced at least 2 meters apart:
    - **Pit 1:** Directly bound to the lightning arresters via heavy copper flats.
    - **Pit 2:** Secured directly to the secondary LV neutral terminal bushing.
    - **Pit 3:** Bonded to the main transformer tank structure, steel installation brackets, and metallic G.O. operating handle.
- **Target Resistance:** Total ground loop resistance across all setups must not exceed **2.0 Ohms** under dry earth contexts.

(6) Testing and Acceptance Criteria

All transformers must undergo a rigorous testing regime to verify compliance with NEA guidelines, relevant **IEC 60076**, and **IS 1180 / IS 2026** standards before they are accepted into the network.

A. Type Tests

The manufacturer must submit certified type test reports from an independent, internationally accredited laboratory (such as CPRI, ERDA, or equivalent KEMA-approved labs) performed on a transformer of identical design and rating within the last 5 years. If valid reports are unavailable, these tests must be conducted at the contractor's expense:

- **Temperature Rise Test:** To verify that winding and top-oil temperature limits are not exceeded.
- **Lightning Impulse Withstand Test:** Standard 1.2/50 µs wave shape on all high-voltage terminals.
- **Short-Circuit Dynamic Ability Test:** To prove mechanical and thermal stability under fault conditions.

B. Routine Tests (Factory Acceptance Tests - FAT)

Every single unit supplied under the contract must successfully pass routine tests at the manufacturer's works. These tests will be witnessed by designated inspectors/engineers prior to dispatch clearance:

- **Measurement of Winding Resistance:** Performed on all phases at the highest, lowest, and nominal tap positions.
- **Voltage Ratio & Vector Group Verification:** To confirm the **Dyn11** configuration and voltage transformation ratios.
- **Impedance Voltage & Load Loss Measurement:** Conducted at rated current and corrected to 75°C. **Losses must not exceed the maximum values guaranteed in the technical data sheet.**
- **No-Load Loss & Excitation Current Measurement:** Checked at rated voltage and frequency.
- **Insulation Resistance (Megger Test):** HV-LV, HV-Earth, and LV-Earth.
- **Induced Over-Voltage & Separate-Source AC Dielectric Withstand Tests:** Standard high-voltage insulation tests.
- **Oil Breakdown Voltage (BDV) Test:** Insulating oil sampled from the transformer must achieve a minimum breakdown strength of **60 kV** (before filling) and **40 kV** (after filling/prior to energization).

C. Field Acceptance & Pre-Commissioning Tests

Following delivery and installation on the pole structure in Nepal, the contractor must perform site tests in the presence of the Project Manager before the transformer is energized:

- Visual inspection for oil leaks, structural damage during transit, and proper paint/galvanization finish.
- Insulation resistance (Megger) checks on windings and the complete earthing set.
- Verification of proper phase sequence and neutral connection to the designated earth pit.
- Measurement of the **individual and combined earth pit resistance** (must be less than 2.0 Ohms).

(7) Measurement

- **Unit of Measurement:** The work layout described will be measured on a **Unit (Set / Number)** basis.
- **Scope of Count:** Each completed, tested, and fully functional installation of a pole-mounted distribution transformer structure (regardless of the specific capacity: 25, 50, 100, 150, or 200 kVA) counts as one complete unit.

(8) Payment

- Design, manufacturing, testing, supply, delivery, and performance requirements of three phase distribution transformers of different capacities with accessories including earthing set measured as above, shall be paid at the contract unit price per set, as established in the approved **Bill of Quantities (BOQ)**.
- **Inclusions in the Unit Rate:** The accepted contract rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications and constitutes full compensation for all associated activities, including but not limited to:
    - **Equipment & Tools:** Supply, transportation, safe handling, lifting, and secure mounting of the transformer tank onto the H-pole steel channels.
    - **Complete Accessory Kit:** Supply, alignment, and termination of the **Lightning Arresters (L.A.)**, **Drop Out (D.O.) Fuses**, and **Gang Operated (G.O.) Switches**.
    - **Civil & Earthing Works:** Excavation of earth pits, supplying salt/charcoal or bentonite chemical compounds, driving earthing rods/pipes, and routing heavy copper/GI grounding wires to the three separate isolated points.
    - **Testing Costs:** All labor, calibrated testing instruments, and documentation required to

successfully complete the Factory Acceptance Tests (FAT) and site commissioning tests.

- **Labor & Materials:** All structural nuts, bolts, washers, jumper wires, PG clamps, bimetallic lugs, labor, overheads, insurance, and incidentals necessary to deliver the installation "all complete" and ready for grid connection.

2307 STANDARD STAY SET

(1) General

This section covers the general requirements of design, manufacture, testing and dispatch of Standard Stay Set for the electric pole in overhead line construction. Stay Set are used for supporting lateral loads due to abnormal wind or angular deviation of alignment or unbalanced loading.

(2) Material

The raw materials for the manufacturing of these line materials are to be conformed IS 2062-1992 (Grade A) and the fabrication shall conform to IS-7215-1974, as amended up to date.

The contractor should galvanize the Board's black tower materials, line materials and other materials in accordance with IS: 2629-1966 and IS: 4759-1968 with Hot Dip process.

Stay Wires - Hard drawn galvanized steel wires should be used as stay wires. The wire shall be circular and free from scale, irregularities, imperfection, flaws, splits and other defects The tensile strength of these wires shall not be less than 70 kgf/mm^2 conforming to IS: 2141-1979, IS: 4826-1979 & IS: 6594-1974. Only standard wires should be used for staying purpose.

The wires shall be drawn from steel made by the open hearth basic oxygen or electric furnace process and of such quality that when drawn to the size of wire specified and coated with zinc, the finished strand and the individual wires shall be of uniform quality and have the properties and characteristics as specified in this specification. The wires shall not contain Sulphur and phosphorus exceeding 0.060% each. The wires shall be of tensile grade 4, having minimum tensile strength of 700 N/mm^2 conforming to 1S:2141.

Stay Rods - Mild steel rods should be used for stay rods. The tensile strength of these rods shall not be less than 42 kgf/mm^2. The threads on the Anchor Rod, Eye Bolt & Nuts shall be as per specification IS: 4218:1967.

Stay Anchoring - Stays should be anchored either by providing base plates of suitable dimensions or by providing angle iron or rail anchors of suitable dimensions and lengths.

Bolt and Washer – Bolt and washer of suitable size shall conform to IS: 1367 & IS: 1363.

Stay Insulator – Stay Insulators are placed to prevent the lower part of wire from becoming electrically energized by upper parts when conductor snaps fall on them due to leakage. Insulator shall be located above 3.50m from ground. The porcelain insulator shall be mechanically strong, sound, free from defect and smoothly glazed.

Thimbles – The Thimbles shall be neatly formed and shall be free from roughness and sharp edges liable to injure the Stay wire. Thimbles materials shall be in compliance with IS 2315:2023. The Thimbles specified are intended for wire ropes used for general engineering purposes.

Turn Buckle – Turn buckle shall be mounted at the end of stay wire. The material shall comply with IS 3121**.** The cross-head shall be made of forged mild steel or channel iron. The sides of each bow shall be well riveted into the cross-head and shall not get pulled-out from the crosshead when the tightener is tested for fracture by tensile tests. The other end of rod shall be rounded into a circular eye of 40mm inner dia with proper and good quality welding.

(3) Welding

The welding shall be conforming to relevant IS: 823/1964 or its latest amendment.

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(4) Tolerances

Stay Wires - A tolerance of (+) 2.5% on the diameter of wires before stranding shall be permitted.

(5) Test and Standard of Acceptance

The stay wires shall be subjected to the following tests in accordance with IS: 2141:

a) Ductility Test

b) Tolerance on Wire Diameter

The completed strand shall be tested for the following tests in accordance with IS: 2141.

a) Tensile and Elongation Test: The percentage elongation of the stranded wire shall not be less than 6%.

b) Chemical analysis

c) Galvanizing test

The test for other components shall be as follows:

a) Breaking Load test on Assembled Stay Rod and Stay Tightener

b) Breaking Load test on Stay Clamp

c) Tolerance on dimensions

d) Galvanizing test of each part of the assembly.

(6) Measurement

Providing and Installing of Stay set arrangements shall be measured in sets as per Drawing or as specified in the contract.

(7) Payment

Providing and Installing of Stay set arrangements measured as above, shall be paid at the contract unit rate. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

2308 ELECTRIFICATION WORKS

This section covers the essential requirements and precautions regarding wiring installations for ensuring satisfactory and reliable service and safety from all possible hazards. This section also covers guidelines for the installation of main switch, busbar strips, distribution boards, lighting fixtures, sockets, fans, street light pole and earthing system.

2309 LIGHTING SYSTEM

This section covers the essential requirements and precautions regarding wiring installations for ensuring satisfactory and reliable service and safety from all possible hazards. This section also covers guidelines for the installation of main switch, busbar strips, distribution boards, lighting fixtures, sockets, fans, street light pole and earthing system.

(1) LIGHTING FIXTURES AND ACCESSORIES

a) General

All lighting fixtures and accessories shall be designed for continuous operation under atmospheric conditions existing at site, without reduction in the life or without any deterioration of materials, internal wiring.

b) Temperature Rise

All lighting fixtures and accessories shall be designed to have a low temperature rise according to the

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relevant Indian Standards. The design ambient temperature shall be taken as 50°C.

c) Supply Voltage

Lighting fixtures and accessories meant for 240V A.C. operation shall be suitable for operation on 240V A.C. 50Hz, supply voltage variation of ± 10%, frequency variation of ± 5% and combined voltage and frequency variation of ± 10%. Lighting fixture and accessories meant for 30V DC operation shall be suitable for operation on 30V DC with variation between 90% to 110% rated voltage.

d) Lighting Fixtures

The lighting fixtures shall be Phillips or Bajaj or Crompton Greaves or equivalent. The different types of lighting fixtures are as indicated elsewhere in this Section.

i. All fixtures shall be designed for minimum glare. The finish of the fixtures shall be such that no bright spots are produced either by direct light source or by reflection.

ii. All lighting fixtures shall utilize LED (Light Emitting Diode) technology. Legacy light sources (such as fluorescent, incandescent, mercury vapour, or sodium vapour lamps) are strictly prohibited unless explicitly requested for highly specialized applications.

iii. All lighting fixtures shall be complete as specified and shall be suitably wired up.

iv. High beam fixtures shall be suitable for pendant mounting and flood lights shall have suitable base plate / frame for mounting on steel structural member. Hook mounted high beam fixtures are not acceptable.

v. Each lighting fixture shall be provided with an earthing terminal suitable for connection to 16 SWG GI earthing conductors.

vi. All light reflecting surfaces shall have optimum light reflecting co-efficient such as to ensure the overall light output as specified by the manufacturer.

vii. Height of fixtures should be such that it is easy to replace with normal ladder/stool. In case the ceiling height is very high, the fixtures may be placed on the walls for ground lighting.

(2) ACCESSORIES

a) Reflectors

The reflectors shall be manufactured from sheet steel or aluminum as applicable of not less as 22 SWG thickness. They shall be securely fixed to the captive type.

b) Capacitors

i. The capacitors shall have a constant value of capacitance and shall be connected across the supply of individual lamp circuits.

ii. The capacitors shall be suitable for operation at supply voltage as specified and shall have a value of capacitance so as to correct the power factors of its corresponding lamp circuit to the extent of 0.98 lag.

iii. The capacitors shall be hermetically sealed in a metal enclosure.

c) Lamps

i. General Lighting Services (GLS) lamps shall be provided with screwed caps and shall be of 'clear' type unless otherwise specified.

ii. Flexible conduits if required, for any fixture shall be deemed to be included in Contractor’s scope.

d) Receptacles

All receptacles shall be of cast steel/aluminum, heavy duty type, suitable for fixing on wall/column and complete with individual switch.

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e) Switch And Switchboard

i. All switch boards/boxes shall be of bent steel construction, fabricated of 16 SWG sheet with 6 mm thick Bakelite or 3 mm thick Perspex sheet cover.

ii. Switch board/boxes located in office/building areas shall be flush mounted type or brick wall with only the switch knob projecting outside.

iii. Switch boards/boxes shall have conduit knock outs on all the sides. Adequate provision shall be made for ventilation of these boxes.

iv. Flush type receptacles provided shall be so located that only the plug project outside.

v. Switches shall be of piano key type having quick make and quick-break mechanism complete with position indicator and shall conform to relevant Standard.

vi. All the components housed in the switchboard shall be wired to an outgoing terminal block by 2.5 sq.mm. Stranded copper wire The terminal block shall be adequately rated

vii. The exact number of switches including regulator for fans and layout of the same in the switchboard shall be to suit the requirement during installation.

f) Conduits & Conduit Accessories

All conduits accessories shall conform to relevant IS.

g) Junction Boxes

i. The junction boxes shall be suitable for mounting on walls, columns, lighting poles, structures etc.

ii. Junction boxes shall be of square/rectangular type of 1.6 mm sheet steel with minimum 6 mm thick pressure die cast aluminum material LM-6 and shall have bolted cover with good quality gasket lining.

iii. The junction box and cover shall be hot dip galvanized.

iv. The junction boxes shall be complete with conduit knockouts/threaded nuts and provided with terminal strips. The junction boxes shall be suitable for termination of conduit/glands of dia 20 mm, 25 mm, 32 mm, 40 mm on all sides. The junction boxes shall be provided with 4 way terminals suitable for two numbers 10 sq. mm. wire & for street lighting/switchyard lighting suitable for 2 numbers 4C x 16 Sq.mm Al. cable.

v. The junction boxes shall have the following indelible markings

   a. Circuit Nos. on the top.

   b. Circuit Nos. with ferrules (inside) as per drawings.

   c. DANGER sign in case of 433-volt junction box.

vi. The junction boxes shall be weather proof type with gaskets conforming to IP-55 as per IS: 13947 (Part-I). The conduit connections shall also be properly sealed to prevent entry of water. The shade of paint for Junction Box shall be of 697 of IS: 5 and the thickness of paint shall be of min. 55 micron.

h) Terminal Blocks

Each terminal shall be suitable for terminating up to 2 Nos. 10 sq.mm stranded Aluminum Conductors without any damage to the conductors or any looseness of connections. Terminal strips provided in outdoor junction box street - lighting poles shall be suitable for terminating up to 2 nos. 4C x 16 sq. mm aluminum cables.

i) Pull Out Boxes

i. The pull out boxes shall be suitable for mounting on walls, column, structures etc. The supply of bolts, nuts and screws required for the erection shall be included in the installation rates.

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ii. The pull out boxes shall be circular of cast iron or 16 SWG sheet steel and shall have cover with good quality gasket lining.

iii. The pull out boxes and cover shall be hot dip galvanized.

iv. The pull-out boxes shall be completed with conduit knock outs/threaded hubs and provided at approximately 3 meters intervals in a conduit run.

v. The pull out boxes used outdoor shall be weather proof type with gaskets conforming to IP-55 as per IS: 13947 (Part-I).

j) Lighting Panels (L.P.)

Each panel shall be provided with one incoming triple pole switch fuse unit with neutral link and outgoing miniature circuit breakers. The panels shall conform to IS/IEC 61439.

The Outdoor and Street Lighting panels shall be provided with a timer device having twenty-four-hour hand set dial with a facility for setting ON & OFF times. The main contacts shall be rated equal to the rating of main contacts in the incomer. There will be a provision of selecting either the manual control or the automatic control.

Constructional Features of Panels:

i. Panels shall be sheet steel enclosed and shall be dust, weather and vermin proof. Sheet steel used shall be of thickness not less than 2.00 mm (cold rolled) or 2.5 mm (hot rolled) smoothly finished, leveled and free from flaws. Stiffeners shall be provided wherever necessary.

ii. All outdoor panels and panels located in damp atmosphere shall have degree of protection not less than IP-55 as per IS: 13947 / (Part-I). All indoor panels shall have degree of protection not less than IP-52 as per IS: 13947 (Part-I).

iii. The panels shall be of single front construction, front hinged and front connected, suitable for either floor mounting on channels, sills or on walls/columns by suitable M.S. brackets.

iv. Panels shall have a dead front assembly provided with hinged door(s) with padlocking arrangement with single key supplied in duplicate.

v. All doors, removable covers and plates shall be gasketed all around with specified gaskets.

vi. The panels shall be suitable for cable/conduit entry from the top and bottom. Suitable removable cable gland-plate shall be provided on the top and bottom of panels. Necessary number of double compression cable gland shall be supplied, fitted on to this gland plate. The glands shall be screwed on top and made of tinned brass.

vii. The panels shall be so constructed as to permit free access to connection of terminals and easy replacement of parts.

viii. Each panel shall have a caution notice fixed on it.

ix. Each panel shall be provided with a circuit directory plate (of anodized aluminum with the inscriptions indelibly etched on the plate) which is fitted on the inside of the door.

x. Each lighting panel shall be provided with one no. ‘ON’ indicating lamp for each phase along with fuses.

k) Main Bus Bars

Bus bars shall conform to IS: 5082 and shall have adequate cross-section to carry the rated continuous current without exceeding the specified temperature limits and withstand short circuit currents. Maximum operating temperature of the bus bars shall not exceed 85°.

l) Miniature Circuit Breaker (MCB)

i. The miniature circuit breakers shall be suitable for manual closing, opening, automatic tripping under overload and short circuit. The MCBs shall also be trip free.

ii. Single pole as well as three pole versions shall be furnished as required in the Schedule of

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Lighting Panels.

iii. The MCBs and panel incomer fuse together shall be rated for full fault level. In case the MCB rating is less than the specified fault level the contractor shall co- ordinate these breaker characteristics with the backup fuse in incomer switch fuse unit in such a way that if fault current is higher than breaker rating, the fuse should blow earlier than the breaker. If the fault current is less than MCB breaking capacity, MCB shall operate first and not the incomer fuse.

iv. The MCBs shall be suitable for housing in the lighting panels and shall be suitable for connection with stranded copper wire connection at both the incoming and outgoing side by copper lugs or for bus bar connection on the incoming side.

v. The terminals of the MCBs and the 'open' 'close' and 'trip' conditions shall be clearly and indelibly marked.

vi. The contractor shall check and co-ordinate the ratings of MCBs with respect to starting characteristics of discharge lamps. The contractor has to furnish overload and short circuit curve of MCB as well as starting characteristics curves of lamps for Owner's approval.

vii. The MCB shall generally conform to IS: 8828 IS/IEC 60898-(Part-1).

m) Ceiling fans and regulators

i. The contractor shall supply and install 1400 mm sweep ceiling fans complete with electronic regulator and switch, suspension rod, canopy and accessories as per the requirement.

ii. The contractor shall supply and install the switch, electronic regulator and board for mounting switch and electronic regulator.

iii. Winding of the fans and regulators shall be insulated with Class-E insulating material. Winding shall be of copper wire.

iv. Electronic regulator with smooth control shall be provided.

v. Fans and electronic regulators shall be of Crompton Greaves /Bajaj Electricals/Usha Electricals make of equivalent.

n) Lighting wires

i. The wiring used for lighting shall be standard products of reputed manufacturers.

ii. The wires shall be of 1100 V grade, PVC insulated product of reputed manufacturers.

iii. The conductor sizes for wires used for point wiring beyond lighting panels shall be single core 4 sq. mm. 6 sq.mm and 10 sq.mm stranded aluminum wires and 2.5 sq.mm, 4 sq.mm, 6 sq.mm and 1.5 sq.mm stranded copper wire.

iv. The wires used for connection of a lighting fixture from a nearest junction box or for loop-in loop-out connection between two fluorescent fixtures shall be single core copper stranded conductor, 1100V grade flexible PVC insulated cords, unsheathed, conforming to IS:694 with nominal conductor cross sectional areas of 2.5 sq. mm.

v. The wires shall be colour coded as follows:

Red for R - Phase Yellow for Y - Phase Blue for B - Phase Black for Neutral White for DC (Positive) Grey for DC (Negative)

(3) Painting Of Shop Made Items

i. All sheet steel work shall be phosphated in accordance with the following procedure and in accordance with IS: 6005 'Code of Practice for Phosphating Iron and Steel'.

ii. Rust and scale shall be removed by pickling with dilute acid followed by washing with running water, rinsing with slightly alkaline hot water and drying.

iii. After phosphating through rinsing shall be carried out with clean water, followed by final rinsing with diluted dichromate solution and oven drying.

iv. The phosphate coating shall be sealed by the application of two coats of ready mixed stoving type metal primer (comprising of red oxide and Zinc chromate in a synthetic medium). The first coat may be 'flash dried' while the second coat shall be stoved.

v. After application of the primer, two coats of finishing synthetic enamel paint shall be applied with each coat followed by stoving. The second finishing coat for the external of panels shall be applied after completion of tests.

vi. Both outside and inside of lighting panel, sheet metal fabricated junction boxes etc. and outside of lighting fixtures shall be finished in light gray (IS-5 shade 631). Inside of lighting fixtures shall be finished in white.

vii. Each coat of primer and finishing paint shall be of slightly different shade so as to enable inspection of the painting.

viii. The final finished thickness of paint film on steel shall not be less than 100 microns and shall not be more than 150 microns.

ix. Finished painted appearance on equipment shall present on aesthetically pleasing appearance, free from dents and uneven surfaces.

(4) Tests And Test Reports

All the items covered under this section should be type tested, design, conforming to the relevant standard.

(5) Measurement

Providing and Installing of lighting arrangements shall be measured in sets as per Drawing or as specified in the contract.

(6) Payment

Providing and installing of lighting arrangements measured as above, shall be paid at the contract unit rate. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

2310 LIGHTING SYSTEM INSTALLATION WORKS

(1) General

In accordance with the specified installation instructions as shown on manufacturer’s drawings or as directed by Owner, Contractor shall unload, erect, install, test and put into commercial use all the electrical equipment included in the contract. Equipment shall be installed in a neat, workmanship manner so that it is level, Plumb Square and properly aligned and oriented. Tolerances shall be as established in manufacturers drawing or as stipulated by Owner.

All apparatus, connections and cabling shall be designed so as to minimize risk of fire or any damage which will be caused in the event of fire.

(2) Conduit System

Contractor shall supply, store and install conduits required for the lighting installation as specified. All accessories/fittings required for making the installation complete, including but not limited to pull out boxes as specified in specification. Ordinary and inspection tees and elbow, checknuts, male and female bushings (brass or galvanized steel), caps, square headed make plugs, nipples, gland sealing fittings, pull boxes, conduits terminal boxes, glands, gaskets and box covers, saddle terminal boxes, and all steel supporting work shall be supplied by the Contractor. The conduit fittings shall be of the same material as conduits.

All unarmored cables shall run within the conduits from lighting panels to lighting fixtures, receptacles. etc. Size of conduit shall be suitably selected by the Contractor.

Conduit support shall be provided at an interval of 750 mm for horizontal runs and 1000 mm for vertical runs. Conduit supports shall be clamped on the approved type of spacer plates or brackets by saddles or

U-bolts. The spacer plates or brackets in turn, shall be securely fixed to the building steel by welding and to concrete or brick work by grouting or by nylon rawl plugs. Wooden plug inserted in the masonry or concrete for conduit support is not acceptable.

Where conduits are along with cable trays they shall be clamped to supporting steel at an interval of 600 mm.

For directly embedding in soil, the conduits shall be coated with an asphalt-based compound. Concrete pier or anchor shall be provided wherever necessary to support the conduit rigidly and to hold it in place.

For long conduit run, pull boxes shall be provided at suitable intervals to facilitate wiring.

Conduit shall be securely fastened to junction boxes or cabinets, each with a lock nut inside and outside the box. Conduits joints and connections shall be made through water-tight and rust proof by application of a thread compound which insulates the joints. White lead is suitable for application on embedded conduit and red lead for exposed conduit.

The entire metallic conduit system, whether embedded or exposed, shall be electrically continuous and thoroughly grounded, if applicable. Where slip joints are used, suitable bounding shall be provided around the joint to ensure a continuous ground circuit.

Conduits and fittings shall be properly protected during construction period against mechanical injury. Conduit ends shall be plugged or capped to prevent entry of foreign material.

(3) Wiring

Wiring shall be generally carried out by PVC wires in conduits. All wires in a conduit shall be drawn simultaneously. No subsequent drawings of wires are permissible.

Wires shall not be pulled through more than two equivalent 90 deg. bends in a single conduit run. Where required, suitable junction boxes shall be used. Wiring shall be spliced only at junction boxes with approved type terminal strip.

For lighting fixtures, connections shall be ted off through suitable round conduit or junction box, so that the connection can be attended without taking down the fixture.

For vertical run of wires in conduit, wires shall be suitably supported by means of wooden/hard rubber plugs at each pull/junction box. Maximum two wires can be terminated to each way of terminal connections.

Separate neutral wires are to be provided for each circuit. AC and DC wiring should not run through the same conduit.

(4) Lighting Panels

The lighting panels shall be erected at the locations to be finalized during detailed engineering.

Suitable foundations/supporting structures for all outdoor type lighting panels and necessary supporting structures for indoor lighting panels shall be provided by the Contractor.

(5) Foundation & civil works

Foundation for street lighting poles and panel foundation and transformer foundation shall be done by the Contractor. The rates for these civil works shall be included in the erection rates of respective items.

All final adjustment of foundation levels, chipping and dressing of foundation surfaces, setting and grouting of anchor bolts, sills, inserts and fastening devices shall be carried out by the Contractor including minor modification of civil works as may be required for erection.

Any cutting of masonry/concrete work, which is necessary shall be done by the Contractor at his own cost and shall be made good to match the original work.

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2311 AC DISTRIBUTION BOARD

(1) Introduction

This chapter covers specification of indoor AC Distribution board for catering power supply to 33kV and 11kV equipment, illumination, battery charger and other auxiliary loads of the sub-station. Incoming power supply to the board will be provided from outdoor station transformer.

(2) Standards

The equipment shall be manufactured as per following standards:

IS: 8623/1933 – Low voltage Switchgear and control gear assemblies. IS: 13947 Part 2 – Low voltage circuit breakers.

(3) Constructional Feature

Panels shall be completely metal enclosed and shall be dust, moisture and vermin proof and fully compartmentalized. The enclosure shall provide a degree of protection not less than IP-52 (for indoor) in accordance with IS: 13947 and the necessary gasket shall be provided as per section-I (Introduction and general technical requirements). It should be free standing, floor mounting type and smooth finished, made of cold rolled sheet steel of thickness not less than 3 mm for weight bearing members of the panels such as base frame, front sheet and door frames, and 2.0 mm for sides, door, top and bottom portions. There shall be sufficient reinforcement to provide level transportation and installation. Design, materials selection and workmanship shall be such as to result in neat appearance, inside and outside with no welds rivets or bolt head apparent from outside, with all exterior surfaces tune and smooth. The colour of the finishing paint shall be Smoke grey in accordance with shade no.692 of IS: 5 or in matching colour of other existing Panels. There shall be space heater with thermostat, illumination lamp and one 3-pin, 15 Amp. power point with socket in the panel.

The cable entries shall be from bottom. Gland Plates and electroplated brass cable glands shall be provided. Cable clamping arrangements shall be provided.

The board shall be mounted on a base frame made of 75x50x6 mm ISMC painted black. It shall be grouted to the floor. The board can also be wall mounted with suitable mounting arrangements.

(4) Painting

All sheet steel work shall be phosphated in accordance with the IS:6005 "Code of Practice for Phosphating Iron and Steel".

Rust, scale, oil, grease, dirt and swarf shall be removed by 7 tank process.

After phosphating, thorough rinsing shall be carried out with clean water followed by final rinsing with dilute dichromate solution and oven drying.

The phosphate coating shall be sealed with application of two coats of ready mixed, stoved type zinc chromate primer. The first coat may be "flash dried" while the second coat shall be stoved.

After application of the primer, two coats of finishing synthetic enamel paint shall be applied, each coat followed by stoving. The second finishing coat shall be applied after inspection of first coat of painting. The exterior colour of paint shall be of a slightly different shade to enable inspection of the painting. The final coat should present a hard glass finish.

A small quantity of finished paint shall be supplied for minor touching up required at site after installation of the panels.

In case the bidder proposes to follow any other established painting procedure like electrostatic painting or powder coating, the procedure shall be submitted for POWERGRID's review and approval.

(5) Technical Detail

Incomer will be from 415 volt 3-phase, 4 wire, 200A MCCB of 10kA interrupting capacity and 10 kA short

time rating for 1 sec. The board shall have isolated bus bar chamber for main bus bar at top, running throughout the length of the board and TPN vertical busbar chambers for power supply to outgoing feeders. The bus bar and connecting links etc. shall be of electrolytic aluminum. All nuts and bolts shall be electro galvanized.

General feeder arrangement will be as follows but actual number of incomer and outgoing feeder will be mentioned in BPS.

Incomer: 1no. 200 Amp TPN MCCB with Over Current and Short Circuit protection.

Outgoing: 4No. 63 Amp. TPN MCCB and 2 Nos. 32Amp TPN MCCB of 10 kA interrupting capacity and 10 kA short time rating for 1 sec. These will be provided with Over Current and Short Circuit protection.

Metering module:

i. Incomer Panel: 1 no. Metering module shall consist of voltmeter with selector switch (1 no.), Ammeter with selector switch (1no), indication lamps (3 nos) for phase health indication. CT operated 3 phase 4 wire energy meter along with CTs.

ii. Outgoing Feeder Panel: 1 no. Ammeter with selector switch for each outgoing feeder.

(6) Earthing

One Earth bars of Aluminum shall be provided near the base. The earth bar shall be connected to two earth terminals. The earth terminals shall be connected to station earth.

2312 XLPE AND ABC CABLE

A. **CROSS LINKED POLYETHYLENE INSULATED POWER CABLE**

11kV (XLPE INSULATED POWER CABLE)

(1) Scope

This Specification covers the 12 kV three-core cross-linked polyethylene (XLPE) insulated power cable. The cable is intended to be used in 11 kV distribution systems.

(2) Design requirement

a) General

The 12 kV power cable shall be cross-linked polyethylene insulated, PVC separation sheathed, steel tape armored and PVC outer sheathed.

b) Conductor

The conductor shall consist of compact round stranded hard drawn aluminium or copper wires. They shall comply with the latest IEC publication. The maximum conductor temperatures shall be 90°C.

c) Insulation

Each conductor shall be wrapped with a layer of semi-conducting tape or free stripping extrusion as a conductor (strand) screen. The conductor shall be insulated by cross-linked polyethylene material (XLPE). The XLPE layer shall be surrounded by insulation screen of semi-conducting tape or free stripping extrusion. Above the insulation screen a metallic screen of plain copper tape shall be provided. All three conductors shall be assembled together with fillers and bound with a tape which shall be again warped in PVC inner covering.

d) Armour

A double layer of galvanized steel tape shall be provided for mechanical protection of the cable.

e) Outer covering

The outer covering of the cable shall be black PVC suitable for the operating temperature of cable and shall meet the requirements of the IEC standards.

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f) Tolerance of Thickness

The minimum thickness at any point shall not fall below the nominal value by more than 0.1 mm plus 10% of the nominal value.

g) Tolerance of Separation Sheath or Outer Sheath

The minimum thickness at any point shall not fall below the nominal value by more than 0.2mm plus 2% of the nominal value.

(3) Tests

The following tests shall be carried out on the cables as per IEC 60811

a) Type tests

- Tests on the conductor:
    - Tensile test
    - Wrapping test
    - Resistance test
- Tests for thickness for insulation and sheath
- Physical tests for insulation
    - Tensile strength and elongation at break
    - Ageing in air oven
    - Shrinkage test
    - Hot deformation
    - Bleeding and blooming test
- Partial discharge test
- Bending test
- Dielectric power factor test
    - As a function of voltage
    - As a function of temperature
- Insulation resistance test
- Heating cycle test
- Impulse withstand test
- High voltage test
- Flammability test

b) The following routine tests shall be made on the completed cable at the manufacturer's plant in accordance with IEC 60811

- Appearance test
- Construction test
- High voltage test
- Partial discharge test
- Insulation resistance test

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(4) Cable drum

The cable drum shall be non-returnable and shall be made of timber, pressure impregnated against fungal and insect attack. Alternatively, cable drums may be made of steel suitably protected against corrosion.

(5) Voltage and Phase Identification

a) The plastic overseath shall be embossed with the name of the manufacturer, number of conductors, the cross-section, type of insulation followed by:

Electric Cable: 12,000 Volts

b) Phase identification for three core cables shall be in accordance with the following:

Phase A (R) : Red

Phase B (S) : Yellow

Phase C (T) : Blue

(6) Size and Quantity

a) Ratings for required quantity of the power cable shall be as shown in Table 1:

TABLE 1: RATINGS AND FEATURES		
XLPE INSULATED POWER CABLE		
1	Nominal system voltage, kV	11
2	Cable Sizes, mm2	As specified
3	AC test voltage for 5 min, kV	15
4	Insulation level;	
	- Power frequency withstand, rms kV	28
	- Impulse withstand, kV	75
5	Applicable standard	IEC 60502

(7) Inspection

All tests and inspections shall be made at the place of manufacture unless otherwise especially agreed upon by the manufacturer and purchaser at the time of purchase. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities without charge, to satisfy him that the material is being furnished in accordance with the specification.

B. ARIAL BUNDED CODUCTORS (ABC)

B.1 SELF SUPPORTING LV ARIAL BUNDLED CONDUCTORS (ABC)

(1) Scope

This Specification covers the 0.6/1 kV three-core link cross-linked polyethylene (XLPE) insulated self-supporting aerial bundled conductors (ABC) for use in the construction of 230/400V, 3-phase, 4-wire, ungrounded, distribution network.

(2) Description

a) The cable shall be suitable for use in locations: altitude range 0-2000 meters, typical temperature range – 5° C to 45° C. relative humidity 80-90%.

b) The conductor shall consist of compact round stranded aluminium wires. The conductor shall be insulated by extruded black cross-linked polyethylene (XLPE) material.

c) The complete cable shall consist of four equal-size insulated conductors stranded together, and the direction of lay shall be right-hand. The type of construction shall cause the tensile load to be shared equally among four conductors.

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The other technical specifications of the ABC are given in Table 1: Technical Data.

(3) Standards

The cable shall comply with the latest revision of UK ESI Standard 43-14: "Aerial Bundled Conductor XLPE Insulated for LV Overhead Distribution", or comparable internationally recognized standards which will result in the cable of equal or better quality.

(4) Phase Identification

a) The identification of the conductors shall be provided by means of ribbing on the external surface of the insulation. The neutral conductor shall preferably be marked with a minimum of 12 for 25mm2, 16 for 50mm2 and 20 for 95 mm2 rib spaced evenly around the circumference of the core.

(5) Tests

a) The following tests shall be done in the completed cable at the manufacturers' plant in accordance with referenced ESI, IEC 60502, IEC 60811 or equivalent standards:

CONSTRUCTION TEST

Verification of diameter of conductor, insulated conductor, and thickness of insulation, and so on.

- Test on XLPE
  - Hot set tests
  - Tensile strength at break
  - Elongation at break
  - Shrinkage
- Mechanical tests
  - Breaking load test
  - Bending test
- Electrical tests
  - High voltage test
  - Conductor resistance at 20 deg C.
  - Insulation resistance
- Simulated solar radiation test: The minimum level of solar radiation shall be 1400 W/m^2

b) The cable shall be tested in full compliance with the governing standard, and a certified type test report shall be produced for all tests conducted.

(6) Size and Quantity

a) Size of cable shall be:

3x50mm2 +1X25 mm2 (Phase Conductor + Neutral)

3X25mm2 + 1X25 mm2 (Phase Conductor + Neutral)

(7) Packaging

a) Each reel of the conductors furnished shall contain only one (1) length of conductor.

b) The cable shall be supplied in non-returnable wooden drums. These shall be fully lagged and triple banded to provide adequate protection during transit. All timber shall be treated to provide protection against rot and insects: the treatment process not having deleterious effect on the cable. The drums shall accommodate a 70mm spindle.

c) Maximum size and weight of drum (excluding lagging) shall be:

Diameter: 1600mm

Width: 1000mm

Weight: 1.5 MT (including cable)

d) All reels shall be legibly marked in paint with the following information:

- ❖ Size of conductor
- ❖ Type of conductor
- ❖ Length in meters
- ❖ Net weight of conductor
- ❖ Direction of rolling

TABLE 1: TECHNICAL DATA FOR SELF SUPPORTING LV ABC

Nominal cross-sectional area, sq.mm	25	50	95
Number of core	4	4	4
Form of conductor	Stranded compacted circular		
Number of wires in conductor	7	7	19
Min. diameter of conductor sq.mm	5.8	8.0	11.3
Max. dc resistance of conductor at 20^0 C, ohm/km	1200	0.641	0.320
Min. breaking load of conductor, kN	3.5	7.0	13.3
Min. average thickness of insulation excluding ribs, mm	1.3	1.5	1.7
Min. thickness of insulation at any point mm	1.07	1.25	1.43
Min breaking load of cable, kN	14.0	28.0	53.2

B.2 HV ARIAL BUNDLED CNDUCTORS (ABC) FOR 11 KV LINES

(1) Scope

This Specification covers the 11 kV cross-linked polyethylene (XLPE) insulated self-supporting aerial bundled conductors (ABC) for use in the construction of 11 kV, 3-phase, 3-wire, ungrounded, distribution network.

(2) Description

a) The cable shall be suitable for use in locations: altitude range 0-2000 meters, typical temperature range – 5 ° C to 45° C and relative humidity 80-90%.

b) The conductor shall consist of compact round stranded aluminum wires. The conductor shall be insulated by extruded black cross-linked polyethylene (XLPE) material.

c) The composite cable shall comprise 3 single core cable twisted around a bare aluminum alloy messenger wire, which will carry the weight of the cable.

d) The technical specifications of the ABC are given in Table 1: Technical Data.

(3) Standards

a) The cable shall comply with the latest revision of UK ESI Standard 43-14: "Aerial Bundled Conductor XLPE Insulated for HV Overhead Distribution", or comparable internationally recognized standards which will result in the cable of equal or better quality.

b) The following standards shall also be applicable:

- IS:7098 (part-II) - 2011- cross-linked polyethylene insulated PVC sheathed cables
- IS:8130-2013 - Conductors for insulated cables

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- IS:398 - (part-IV) - 1994 - Aluminum alloy conductors

(4) Details of Single Core Cable

a) The cable conductors shall be round, stranded and compacted aluminum of cross-sectional area 35 mm2and 70 mm2. Diameter and number of wires are given in the Table 1.

b) Conductor Screen

The conductor screen shall be of extruded semi-conducting cross-linked polyethylene compound of thickness not less than 0.5mm.

c) Insulation

The insulation shall be of extruded cross-linked polyethylene (XLPE) of nominal insulation thickness 3.6mm and its properties shall conform to IS: 7098 (part II).

d) Insulation Screen

The insulation screen shall comprise extruded semi-conducting compound and/or semi-conducting tape. Thickness of the screen shall not be less than 0.6mm.

e) Metallic Screen

The metallic screen shall consist of aluminum tape/sheath of thickness not less than 0.2mm.

f) Outer Sheath

The outer sheath shall be of black polyethylene. The nominal thickness of sheath shall be 1.8mm and it shall conform to the technical requirements of ST - 3 of IEC - 60502.

g) Dimensional and Electrical Data

The dimensional and electrical data for single core cables are given below:

• Nominal area of conductors	35 mm^2	70 mm^2
• Nominal conductor diameter (mm)/ No. of wires in conductor	6.8/6	10/12
• Approx. overall dia of cable (mm)	22	25
• Max. DC resistance at 20oC (Ω/km)	0.868	0.443
• Max. SC current for 1 sec. KA	3.4	6.7
• Max. continuous load (Amps.)	106	156

Due to the limitations of short circuit current rating, it is recommended that 70mm^2 cable is used on the base line for the first 4-5 kms from the 33/11 kV substation and thereafter the lower size of cable i.e. 35mm2 can be used depending upon the line loading.

(5) Messenger (Neutral Conductor)

a) The bare messenger wire shall be of 70mm2 (nominal area) aluminum alloy, generally confirming to IS:398 (part-IV) - 1994, comprising of 7 strands and shall be suitably compacted to have smooth round surface to avoid damage to the outer insulating sheath of single-core phase cables twisted around the messenger.

b) There shall be no joints in any wire of the stranded messenger conductor except those made in the base rod or wires before finally drawing.

c) The technical characteristics of the messenger wire shall be as follows:

• Nominal sectional area (mm^2)	70
• No. of wires	7

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- Nominal dia of wires/compacted compacted conductor (Approx.) mm 3.5/10
- Approx. mass Kg/km 184
- DC resistance at 200C Ω/km 0.493
- Breaking load (KN) 20
- Modulus of elasticity (Approx.) KN/mm^2 59
- Coefficient of linear expansion (Approx.) 23x10-6/^{o}C

(6) Designation and Parameters of Finished Cables

The designation and parameters of finished cables are given below:

SN	Designation	Complete Bunched Cable	
		Overall Dia Approx mm	Total mass kg/km approx
1	3x35+70	53	1450
2	3x70+70	59	1900

(7) Tests

The following tests shall be made on the completed cable at the manufacturer's plant in accordance with referenced IS: 7098 (Part-II) or equivalent standards:

a) Type Tests

- Tests on conductor:
  - Tensile test
  - Wrapping test
  - Resistance test
- Tests for thickness of insulation and sheath
- Physical test for insulation:
  - Tensile strength and elongation at break
  - Ageing in air oven
  - Hot test
  - Shrinkage test
  - Water absorption
- Tests for outer sheath:
  - Tensile strength and elongation at break
  - Ageing in air oven
  - Shrinkage test
  - Hot deformation
  - Bleeding and blooming test
- Partial discharge test
- Bending test
- Dielectric power factor test
  - As a function of voltage

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- As a function of temperature

- ❖ Insulation resistance test
- ❖ Heating cycle test
- ❖ Impulse withstand test
- ❖ High voltage test
- ❖ Flammability test

b) Acceptance Test

- ❖ Tensile test
- ❖ Wrapping test
- ❖ Conductor resistance test
- ❖ Test for thickness of insulation and sheath
- ❖ Hot set test for insulation
- ❖ Tensile strength and elongation at break test for insulation and sheath
- ❖ Partial discharge test
- ❖ High voltage test
- ❖ Insulation resistance (volume resistivity) test

c) Routine Tests

- ❖ High voltage test
- ❖ Conductor resistance at 20 deg C.
- ❖ Partial discharge test

d) The following tests shall be carried out on the bare messenger wire in accordance with IS: 398 (Part - IV).

i. Type Tests/ Acceptance Tests

- ❖ Breaking load test (on finished wire)
- ❖ Elongation test
- ❖ Resistance test

(8) Packaging

The cable shall be supplied in non-returnable wooden drums. These shall be fully lagged and triple banded to provide adequate protection during transit. All timber shall be treated to provide protection against rot and insects: the treatment process not having deleterious effect on the cable. The drums shall accommodate a 70mm spindle.

All reels shall be legibly marked in paint with the following information:

- Size of conductor
- Type of conductor
- Length in meters
- Net weight of conductor
- Direction of rolling

(9) Inspection

All the tests and inspection shall be made at the place of manufacture unless otherwise especially agreed upon by the supplier and purchaser at the time of purchase. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities without charge, to satisfy him that material is being furnished in accordance with the specification.

C. MEASUREMENT AND PAYMENT

Stringing of power cables (XLPE cable/ ABC cable) shall be measured in running meter as per Drawing or as specified in the contract.

Stringing of power cables measured as above shall be paid at the contract unit rate which includes cost of cable, cable support accessories, equipment, labor, etc. required. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

SECTION 2400: SUSPENSION BRIDGE WORK

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2401 SCOPE OF WORK

This Section covers different types of suspension, suspended bridge and truss bridge construction and other associated works related to suspension and suspended bridge and truss bridge.

2402 GENERAL

The Contractor shall be responsible for suspension, suspended bridge and truss bridge related works as specified in the contract or on the Drawing in accordance with this Section and other relevant Section of this Specification. Before the work begins, the Contractor shall submit to the Engineer Drawing showing details of the proposed bridge work and other related works as the case may be.

2403 MATERIALS

(1) Wire Ropes

The contractor shall not be responsible for procurement of wire ropes required as these shall be provided to the contractor by the employer from its store. However, the contractor/fabricator concerned shall verify the correct dimension in diameter, length, properly cut ends, and avoid the kinks while receiving the cable from the said store according to the approved check list.

(2) Blasting Materials

As these materials are sensible, destructive, and require special care under security and expert supervision during handling, storing and its use, they are procured under expert guidance and stored in Military facilities, wherever possible. Their specification being earlier verified as per the requirement, it should not be of great concern to the Contractor. Its handling shall be strictly under the GoN law and regulations.

2404 STEEL WORK

Actual fabrication of the bridge parts shall be based on the "Terms of Steel works" given below in addition to relevant ISI Codes. In case of discrepancies between the two, the "Terms of Steelworks" shall prevail.

Safety and health provisions shall be made according to IS: 818-1968, and shall entirely be the Contractor/ Fabricator’s responsibility.

The following “Terms of steel works” has to be strictly followed while performing the steel parts fabrication work.

(a) Straightening

All materials shall be straight and if necessary, before being worked shall be straightened and/or flattened by pressure, unless required to be of curvilinear form and shall be free from twists.

(b) Cutting

Cutting may be affected by shearing, cropping or sawing. Gas cutting by mechanically controlled torch is permitted for mild steel only. Gas cutting of high tensile steel is also permitted provided special care is taken to leave sufficient metal to be removed by machining so that all metal that has been hardened by flame is removed. No loads shall be transmitted into metal (except welded joints) through a gas cut surface.

(c) Holing and Punching

Holes for bolts or pins shall be drilled (not to be formed by gas cutting). Punching may be permitted for materials with thickness < 14mm, provided the holes are punched 3 mm less in diameter than the required size and reamed after punching to the full diameter. When holes are drilled or punched in one operation through two or more separable parts, these parts shall be separated after drilling or punching and the burrs removed. To obtain uniformity the use of templates and jigs is mandatory for holing.

(d) Assembly

The component parts shall be assembled in such a manner that they are neither twisted nor otherwise

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damaged and shall be so prepared that the specified cambers, if any, are provided.

(e) Bolting

Where necessary washers shall be tapered or otherwise suitably shaped to give the heads of nuts and bolts a satisfactory bearing. The threaded portion of each bolt shall project through the nut at least two threads. In all cases where the full bearing areas of the bolt is to be developed, the bolt shall be provided with a washer of sufficient thickness under the nut to avoid any threaded portion of the bolt being within the thickness of the parts bolted together. Threading of rods and holes shall be done by machines.

(f) Welding

Welding shall be in accordance with any of the following standards as appropriate, and shall be conducted by appropriately qualified welders:

IS: 816: Code of practice for use of metal arc welding for general construction in mild steel.

IS: 800: Code of practice for use of welding in bridges and structures

IS: 1024-1999: Subject to dynamic loading.

If there are any new editions of Indian Standard those should be used as references. The use of templates and jigs is mandatory for welding of assembly. Following special requirements in conjunction with galvanization has to be made. Sections should have corners cropped to allow free flow of zinc during galvanization.

Avoid narrow gaps between plates. Overlapping surfaces and back-to-back angles and channels should be avoided. Where small areas are unavoidable edges should be sealed by a continuous pore free weld to prevent penetration of pickle acids.

(g) Long Span Trail Bridge (LSTB) Standard Designs

The LSTB Standard Design and Drawings prepared by Suspension Bridge Division under Department of Local infrastructure (DOLI) shall be the integral parts of this specification as details for the steel works can be found in the set of Standard Steel Drawings.

(h) Quality Requirements, Quality Control and Quality Assurance (Guarantee)

The quality control of the raw materials acquired, fabrication process, and that of readymade product is the responsibility of the prime contractor/fabricator, who should guarantee that all raw materials are of standard quality according to Indian Standards Institution and to the specifications given in the "Terms of Steel works" and fabrication of the bridge parts are correct according to LSTB Design and Drawings. The cost for all damages due to use of low-quality materials shall have to be borne by the contractor/fabricator. At the time of delivery, the parts and materials shall have to be free from any defects in material or workmanship in all respects and shall remain reasonably perfect till the end of maintenance period when a final check shall be carried out.

(i) Inspection, Tests and Final Check

The Contractor/Fabricator shall coordinate to provide access and other facilities for the inspection and, if required, tests of the works at any/or all stages during fabrication of the steel parts. Unless otherwise agreed this inspection should be carried out at the place of fabrication. The inspection shall be facilitated by a properly accredited person (quality control manager) available at the fabricator's floor during all working hours together with a complete set of drawings and any further instructions which may have been issued.

Following steel parts have to be in assembled form during such inspection: The parts shall be assembled after completion of the galvanization, on a flat, level and hard top place. Once dismantled, any damage to the galvanization of the steel parts has to be rectified before delivery.

- All anchorage parts
- Walkway deck with minimum of four crossbeams in assemblage

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- Both towers, complete
- Wind guy stay strut
- Complete truss
- Clamps and turnbuckles

Such inspection shall be made prior to delivery and shall be conducted so as not to interfere unnecessarily with the operation of other work. Such inspections are supplementary and intended to clear the delivery only, and shall not be considered as a final acceptance.

The final check of all steel parts will be conducted along with the final check of the bridge and the discrepancies found during such final check have to be rectified by the Contractor/Fabricator at its own cost. On a default situation, such works shall be conducted by the Employer and the cost incurred for such works shall be made a liability in the Contractor/Fabricator's account (either from its retention money or from other payments and/or their property according to the prevailing rules and regulations).

All gauges and templates, measuring instruments etc. necessary to satisfy the inspector shall be supplied by the manufacturer. The inspector may at his discretion check the test results obtained at the manufacturers works by independent tests and should the material so tested be found to be unsatisfactory, the costs of such tests shall be borne by the manufacturer, and, if satisfactory, the costs shall be borne by the Employer. In any case the quality assurance of Principal Manufacturer has to be made available by the Contractor/Fabricator, whenever required by the Employer.

(j) Storing, handling and protection of steel parts

All structural and reinforcement steel shall be stored and handled without subjecting them to excessive stress and damage. The threaded parts, including anchorage rods, clamps, suspenders etc. have to be protected with grease and jute immediately after completion.

(k) Labeling, Packing and delivery

Bundles of loads of members or set of members shall be prepared for loading, unloading and transportation either by road transportation vehicle or by aircraft. Each member (or set of members) has to be labeled clearly indicating both the drawing number and the part number corresponding to the steel-part list and the drawing number provided by the Employer, but only after galvanization.

Straight bars and plates shall be bundled. All bolts, nuts, washers and other small and loose parts shall be packed in cases or strong bags and labeled in order to prevent damage or distortion during transportation. The Wire mesh netting has to be delivered in bundles. Each transport unit shall not exceed 45 kg in weight. For each delivery the workshop has to prepare a detailed list of the bridge parts to be delivered, containing the drawing numbers, part numbers, and description of parts, quantities and weights.

2405 SUPPLY AND FABRICATION OF STEEL PARTS

- **Structural Steel**

Structural steel supplied by the workshop shall comply with the requirements of IS: 2062, Hot Rolled Medium and High Tensile Structural Steel. The dimensions for hot rolled materials are specified in IS: 800 & 808 (General construction in steel). Steel grade shall be standard quality FE410, and should have following properties:

Yield stress ≥ 250 N/mm^2

Tensile strength ≥500 N/mm^2

Elongation ≥ 23%

Permissible tolerance of physical dimension = ± 2.5%

- **Reinforcement Steel**

Reinforcement steel supplied by the workshop shall be ribbed TOR/TMT steel with high yield strength

deformed bar of grade FE 415 confirming to IS: 1786-1985 and IS: 1786-2008. All reinforcement shall be clean and free from loose mill-scales, dust, loose rust and coats of paint, oil or other coatings which may destroy or reduce bonds. All reinforcement steel shall be cold bent. Points for anchor rods shall be formed by grinding. Joining of reinforcement steel bars by welding is prohibited.

2406 SUPPLY OF THIMBLES

Thimbles supplied by the workshop shall conform to the standard specifications of Thimbles (IS: 2315-2023). The workshop is responsible that all thimbles can be fitted to the provided pins, steel parts etc. Thimbles should be hot dip galvanized with minimum zinc coat of 40μm.

2407 SUPPLY OF BULLDOG GRIPS

Bulldog grips supplied by the workshop shall confirm to the standard specifications of Bulldog grips (IS: 2361-1970). In addition, it also should fulfill the following requirements:

The bridges must be drop-forged and suitably scored to grip a round strand rope of right hand lay having six strands. Bridge, U-bolts and nuts should be hot dip galvanized with minimum zinc coat of 40μm. The thread of U-bolt and nuts on it should withstand specific torque.

The bulldog grips should have minimum grip strength of:

13mm ≥ 2.7 tone, 26mm≥ 6.6 tone, 32mm ≥ 8.3 tone, 36mm ≥ 9.0 tone, 40mm ≥ 9.7 tone,

Note: Thimbles, bulldog grips, nuts, bolts and washers have to be galvanized according to IS: 2629- 1966, and Recommended practice for Hot-dip Galvanizing of Iron and Steel.

2408 PAINTING WORKS

The exposed surface of bridge parts fabricated and assembled shall be properly painted with appropriate paint after surface preparation. After surface preparation, first and second coat shall be applied and shall be finished with final finishing coat to present shining/glowing appearance. Painting works shall be carried out in accordance with section 1400 of this specification.

2409 MISCELLANEOUS SUPPLY

(1) Wire mesh Netting

The wire used for fabrication of wire mesh netting shall be of 10 SWG (3.15 mm), conforming to IS: 280-1978, heavy coat galvanized according to IS: 4826-1979 (hot dip galvanized, minimum zinc coating of 270 gm/m^2 and should pass uniformity of zinc coat and adherence test). In addition, G.I. wire should have tensile strength of 380-500N/mm^2. The meshes shall be of chain link type, mesh size 60 x 60 mm. The width shall be 1.30 m for suspended bridge and 1.2 m for suspension bridge.

(2) Sign Board

Sign board to be erected at construction site shall be as per section 100 of this specification.

(3) Bolts, Nuts & Washers

Bolts, nuts, & washers shall confirm the standard specification of bolts, screws, nuts & washers (IS: 1363 for hexagon head bolts) / (IS: 1367-1979/1980 conditions for threaded fasteners) / (IS: 6610- 1972 for heavy washers) / (IS: 5369-1975 for plane & lock washers) /(IS: 5372-1975 for taper washers). Bolts, nuts & washers shall be hot dip galvanized unless otherwise stated.

(4) Hot Dip Galvanization of Steel Parts

Galvanizing of steel parts shall be executed in accordance with IS: 2629-2025 (Process, Design, Testing and Application of Hot Dip Galvanizing of Iron and Steel) and IS 4759(specification for hot-dip zinc galvanization on structural steel).

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Galvanization Process

Galvanizing should follow the process as below:

- Preparatory work

All welding slag should be removed from the steel parts to be galvanized. Acid traps should be avoided.

- Alkaline cleaning

Rust, oil and other contaminants should be removed from the steel by preliminary treatment with Alkaline cleaning in Sodium Hydroxide Solution of 10 ~ 15%.

- Concentration

The concentration of the solution should be monitored at regular intervals and adjusted accordingly to have good cleaning effect.

- Rinsing

After Alkaline cleaning, steel should be flushed with running water.

- Acid Bath

The preliminary treated steel is then cleaned by Acid Bath in Hydrochloric Acid Solution of 50% concentration.

During the operation, close control of acid content in the solution is necessary. It is done by testing for acid (PH value = 1 to 3, measured by PH meter) and iron contents at regular intervals. The strength of the solution should be maintained by periodic addition of fresh concentrated acid. If the iron content in the solution is more than 100g/liter (density measured by hydrometer, maximum permissible value = 1.2), it should be changed by the new fresh solution.

- Rinsing

After Acid Bath steel should be flushed with running water.

- Pre-flux treatment

Acid bathed steel is dipped in a solution of Zinc Ammonium Chloride (ZnCl23NH4Cl) of 20~ 40% concentration. This solution is prepared by mixing 45% of Zinc Chloride ($ZnCl_2$) + 55% of Ammonium Chloride (NH_4Cl).

The concentration of solution should be controlled at regular intervals. For this specific gravity of the solution is maintained (Hydrometer reading in range of 1.1 to 1.15) by adding required quantities of pre-flux chemicals in proportions.

- Dry

After pre-flux treatment, steel is dried for galvanization.

- Galvanization

The treated steel is dipped into the molted Zinc (zinc bath). Temperature of the molted Zinc should be maintained within the range of 4500 C to 4700 C. Appropriate dipping time also should be maintained.

- Cooling

After the hot dip, steel is cooled with water.

Quality Checking of Galvanization/ Galvanizing Process

- Check the galvanizing plant and it's set up to be ensured that all the galvanizing process is available and maintained.

Quality of Zinc

- This can be checked by chemical testing of raw zinc used for the galvanization. Zinc content should

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not be less than 98.5%.

Quality of galvanization

- By visual check the following:
  - Galvanized steel should be free from rust and black spots, acid traps, welding slags.
  - Galvanized coating should be free from ash, pimples and bulky deposition.
  - Galvanized coating should be continuous, smooth and evenly distributed as far as possible.
- Zinc coat should be adherent. This can be checked by hammering or scratching.
- No zinc paint or aluminum paint is applied to hide rust spots. This is very unhealthy practice, which is frequently applied by the galvanizers.
- Zinc thickness can be measured by Delta scope (electromagnetic instrument for measuring coating thickness over ferrous material). In our case zinc coat should not be less than 80 µm in any steel parts.
- Treatment of Threads: Extra zinc on threads should be removed with a rotating wire brush immediately after galvanizing or with gas blow and cleaning with rotating brush if galvanization is already hardened. Re-threading of the galvanized parts is not permitted.

2410 TRANSPORTATION

It is wholly the responsibility of the Contractor to control transportation activities and quality/quantity of any materials procured or received from the Employer's stores, loading and off-loading of the same, and the delivery at designated site.

(1) Materials and Equipment

- Materials, such as cement and steel parts should be transported with due attention so as not to incur any damage to them either due to exposure to excessive moisture or mishandling. The cement bags to be delivered at site should contain its full original weight viz. 50 kg. The Contractor shall entirely be responsible for the quality and quantity of materials received at the point of origin and their delivery at site in the same quantity and quality. No reasons whatsoever will be accepted for materials not reaching to site in proper condition and in required quantity. Loss during transportation, if any is entirely on the Contractor's account.
- Other materials and equipment shall be transported properly so as to minimize the loss or damage during transportation. Contractor shall have to be cautious not to damage equipment during transportation in order to avoid delay of work.
- In the case of blasting materials, the transportation, handling, storage and use of explosives shall be subject to the laws and regulations of the Government as well as to the instructions of the Employer's Engineer. The Contractor shall maintain an inventory record of storage and withdrawal of all explosives and such information shall be duly communicated to the Engineer. The Contractor shall provide such reasonable and adequate protective facilities as are necessary to prevent loss, theft or damage of explosives. The Engineer shall be informed promptly of any such loss. Security provision should be made accordingly at the Contractor's cost.

(2) Wire Ropes and Bulldog Grips

Wire Ropes and Bulldog Grips supplied from Employer's store shall be under direct responsibility of the Contractor till it is fitted in the bridge. The Contractor must transport them immediately to site with proper handling so that i) cable is not damaged, kinked, or the loose ends opened and ii) Bulldog Grips do not get damaged. It is the Contractors responsibility to check cutting, coiling, and the quantities of cable as well as the quantities of Bulldog grips received from Employer's store, their loading and unloading.

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2411 CONSTRUCTION

The construction works includes civil, mechanical, finishing works together with erection, running and maintenance of the camp.

(1) Site Clearance

The areas to be occupied by the permanent works and any borrow areas shall be cleared of trees, stumps, roots, vegetation, structures and other obstructions to the extent required by the design. All materials thus removed during site clearance shall be the property of the Employer.

(2) All Excavation

All excavation has to be carried out according to design, designed cut slope, designed provision of shuttering, and the safety has to be maintained. All excavation has been classified as follows.

(a) Soil

It is when soil can be removed by shovels, picks or which include big stones of a size which require moving by hand.

(b) Soft Rock

It is when bed rock can be removed by means of crowbars and picks without any blasting.

(c) Hard Rock (by Quarrying out)

This includes quarrying by wedging.

(d) Hard Rock (by Blasting)

The hard rock encountered in foundation excavation has to be removed by blasting it with industrial gelatin, detonator, and adequate length of fuse wire.

(e) Excavation in Shallow Water

It is defined as excavation below the ground water level and includes all necessary measures for dewatering like water courses, ditches, rock pits but without provision and operation of pumps.

(3) Foundation Excavation

Excavation for the permanent construction such as foundation blocks shall be made to the lines, grades and dimensions shown on the drawings. All necessary precautions (including control of blasting) shall be taken to preserve the material below and beyond the established lines of all excavation and also to the safety of workers and others.

When excavated to the required levels and dimensions, the surface has to be cleaned, prepared, and approved by the Engineer prior to the placing of concrete, masonry, or any other filling materials.

The classification of excavation is similar to the aforementioned and listed under following headings

1. Soil (ref. 2410 (2)(a))
2. Soft Rock (ref. 2410 (2)(b))
3. Hard Rock by Quarrying out (ref. 2410 (2)(c))
4. Hard Rock by Blasting (ref. 2410 (2)(d))
5. Hard Rock by Chiseling

Hard rock which cannot be removed by wedging and due to other constraints cannot be blasted, such surface has to be chiseled to acquire the required level and dimensions as per the design, i.e., for finishing the foundation surfaces.

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(4) Backfilling

Common material generally shall be used for backfilling behind civil structures and behind a filter bed of gravel fill as shall be shown in the drawing. Fill material shall be placed in position shown on the drawings and will be obtained from designated borrow areas, excavation on site or any other suitable area, as designated by the design and directed by the Engineer. Backfilling shall be of continuous compacted layers not exceeding 300 mm thickness. In case of retaining wall, proper filter materials for weep holes are to be provided in order to drain out water behind the wall.

All local material required for the construction of the work shall have to be obtained from borrow areas beyond a minimum haulage distance of 30 meters. The Contractor is responsible for any kind of river bank erosion which ultimately may endanger the stability of foundations, as a result of carelessness in collecting local material from such critical areas.

(5) Construction of Gabion

Construction and quality requirement of gabion works shall comply with the requirements given in Section 1500 of this specification.

(6) Concrete Works (Plain Concrete/ RCC/Plum Concrete)

Concrete works as specified in the contract or on the drawing shall confirm the requirements given in Section 800 of this specification.

(a) Cement

Cement required to be used for various works including concrete works as specified in the contract or on the drawing shall confirm the requirements given in Section 800 of this specification.

(b) Sand Collection

Sand required to be used for various works including concrete works as specified in the contract or on the drawing shall confirm the requirements given in Section 800 of this specification. It shall conform to IS 383:2016 too.

(c) Coarse Aggregate

Coarse aggregate required to be used for concrete works as specified in the contract or on the drawing shall confirm the requirements given in Section 800 of this specification. It shall conform to IS 383:2016 too.

(d) Stone

Stone required to be used for various works as specified in the contract or on the drawing shall confirm the requirements given in Section 800 of this specification.

(e) Water

Water for washing aggregates, mixing, and curing concrete shall be fresh and shall be free from objectionable quantities of silt, organic matter, alkalis, salts and other impurities.

(f) Mixing and Placing

Mixing and placing required for concrete works as specified in the contract or on the drawing shall confirm the requirements given in Section 800 of this specification.

(g) Curing and Protection

Concrete shall be cured by maintaining the surface wet (using suitable and approved method) for at least 7 days. Concrete shall be protected from direct rain for 12 hours, from flowing water for 14 days. The contractor shall ensure that no structural and physical damage be inflicted on it.

(h) Reinforcement and Steel Parts

The contractor shall assemble and fix the steel parts and the reinforcement (conforming to 2405) as shown on the drawings. Reinforcement and steel parts stored in neat racks above the ground shall be cleaned of

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all loose rust, mill scale, dirt, grease, paint and other foreign substances and shall be maintained in a clean condition until embedded in concrete.

(7) Formwork

Formwork shall be made from functional, straight and stout timber uniform enough to leave a smooth surface later on.

Formwork shall withstand the pressure resulting from the placement and vibration of the concrete, maintained rigidly in position, and shall be sufficiently tight to prevent the loss of mortar or the water content of the concrete. The Contractor shall ensure the safety and quality during the work. Form work shall only be removed after the minimum stripping times which shall be:

- Non load bearing members and side forms : 3 days
- Load bearing members up to 3m span : 10 days
- Load bearing members up to 6m span : 20 days
- Load bearing members above 6m span : 30 days

(8) Masonry and Mortar Work

(a) Dry Stone Masonry or Pitching

Dry stone masonry or pitching as specified in the contract or on the drawing shall be performed according to Section 700 of this specification.

(b) Cement Masonry

Cement masonry as specified in the contract or on the drawing shall be performed according to Section 600 of this specification.

(c) Cement Plaster

Cement Plaster as specified in the contract or on the drawing shall be performed according to Section 1300 of this specification.

(9) Erection and finishing work

(a) Erection of Towers/Truss Bridge

The Contractor shall be fully responsible for all the necessary safety precautions including the proper temporary fixation of the towers (they are hinged) with the aid of cables anchored to specially designed anchorage blocks and the erection of the truss component of a steel truss bridge. The erection can be executed either with the aid of a bamboo scaffolding or with a suspended platform.

(b) Cable Hoisting

This includes hoisting of all cables together with the placing and fixing of thimbles, bulldog grips and pre tensioning.

The Contractor shall hoist the cable across the river, over onto the top of towers, further to anchorage blocks strictly according to accepted method. The work shall include the correct fitting of all cable terminals either with thimbles and bulldog grips or with sockets. The work shall also include the pre tensioning (proper setting of design sag) of main cables, wind guy/wind tie cables, spanning cables and side stay cables along with the adjustment of stabilizing cables, diagonal stabilizing cables, the correct fitting of handrail and fixation cables as indicated in the drawings. Safety of the workers, materials, and others should be of prime concern during this work, the responsibility for which entirely lies with the Contractor.

(c) Erection of Walkway

The Contractor shall be fully responsible for all the necessary safety precautions during the erection of the walkway. The steel deck has to be properly fitted as specified in the drawings including suspender and cross beams. The wire mesh netting shall be folded around to the handrail cable fixed to the fixation cables and suspenders with binding wire of 12 SWG @ an interval of 30 cm.

All clamps, bulldog grips, nuts etc. shall be retightened upon the completion of the bridge.

Permitted Tolerance for towers after erection of the deck shall be as follows:

- Deviation from verticality : 0.20% of the tower height
- Deviation from straightness : 0.10% of the tower height

Permitted deviations from the hoisting sag specified in the drawings shall be:

- For suspension bridges : + 0.04% of the span
- For suspended bridges : + 0.02% of the span

(d) Protection from soil and debris

All anchorages and foundations shall be cleaned of soil, mud and debris and all possible measures shall be taken to avoid steel parts, cables, etc. from being covered by soil, mud or debris.

(10) Surrounding Works

As soon as practicable, after cutting of a permanent slope, backfilling or the forming of an embankment slope, the Contractor shall encourage the growth of a vegetation cover by turfing or grass showing, transplanting the slope with readymade turf properly cut from another area, and afforestation (planting of trees and plants) as shown in the drawings or as directed by the Engineer. This work includes the care and protection of the plantations from any damage until the end of the period of maintenance. Additional slope and riverbank protection works, such as wicker work fences, brushwood work, and terracing may be required if indicated in the design.

(11) Site Installation and Supervision

This item shall cover the entire erection or hiring of camp, its regular running and maintenance along with the technical supervision of the whole work package.

(a) Site Installation and Site Supervision

Site installation and site supervision of suspension bridge works involve the coordination and management of various activities related to the construction of a suspension bridge.

(b) Camp Construction and Hiring of Camp:

A proper camp site above high flood level and safe from bank erosion shall be established.

The Contractor has to arrange an adequate camp and the necessary equipment for him and his own staff, along with a simple provision of lodging for the visiting technicians of the Employer, at his own cost.

The camp provided for workers/labors shall fulfill minimum requirement for lodging with separate toilets for male and female and shall be according to type design provided by Employer, if any.

Camp area should be sufficient for storeroom for storing cement and steel parts. The rooms must be with waterproof roofing and compacted and moisture proof floor. No surface runoff or any other water should enter the cement store.

Land Rent /Compensation/ Acquisition:

The Contractor has to pay a negotiated land rent/compensation based on the crops lost during the use of land for construction to the landowner. Contractor shall pay them directly and its cost should be included within the camp item. In case of permanent structure occupying a piece of land the acquisition “Muwabja” shall be according to the existing GoN practices and rules/regulations. The implementation of procedure for the land acquisition shall be the responsibility of the Employer. Written permission of landowner or VDC with its cost has to be incorporated in the cost estimate. Employer’s support is limited to make such commitments available only.

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Supervision:

Supervision includes the supervision of fabrication of steel parts, transportation, construction and bridge erection by competent personnel. The entire supervision is the Contractor's responsibility.

The Contractor shall appoint suitably qualified and experienced in the field technician as site staff (min. level overseer) for the purpose of daily supervision of works in each concerned phase.

The site supervisor has to devote full time on the site for the entire project period whereas an engineer of the Contractor has to visit the site for key supervision from time to time and according to the necessity.

Site supervisor/ engineer has to skill fully perform layout, measurement, quality control, test of material, monitor the execution of works as per drawing/ specifications/ schedule, and report the progress in due time to the Employer.

The Contractor shall lay out the designed bridge at the construction site based on the existing survey pegs and reference points. After completion of general layout, the Contractor shall set out all centering and levels and shall work the same with peg level.

Pegs shall be provided close to each structure. The Contractor shall not commence any work until the setting out is complete and checked by the Engineer.

The Contractor shall assist any authorized inspector from the Employer who is inspecting the site. All necessary information and documents must be provided on request and full cooperation on all matters should be given promptly.

2412 MISCELLANEOUS WORKS

(Applicable for maintenance works only)

(1) Gabion Works

Dismantling of Gabion Boxes

The existing gabion crates shall be dismantled before any new work could be carried out. The lid of the crate shall be opened, stones properly removed and stacked for future use, if necessary. The crates themselves have to disintegrate from the good ones that are still functional. Useless boxes shall be dismantled according to the instructions by the Engineer.

(2) Concrete and Masonry Work

Dismantling of Masonry/Concrete Structure

In maintenance work, some part of masonry or/ and concrete has to be dismantled and an entirely new structure or a partial addition of masonry or/ and concrete has to be made. Such cases require the dismantling of masonry and concrete structure. This dismantling could be difficult and shall be performed very carefully so as not to disturb other remaining structures and shall be as designed or instructed by the Engineer.

(3) Pre tensioning of Wire Ropes

The required pretension in any loose cable shall be achieved by pulling them, at first with the use of turnbuckles. If the required pretension cannot be achieved only by adjusting the turnbuckle, the cable end shall be pulled with the help of a cable pulling machine until the designed pretension is achieved, the cable ends properly secured on the corresponding anchorages. This has to be performed according to the Engineer's advice and consent regarding the process and method to be use for the retightening of any cable to required pre tensioning.

(4) Walkway Adjustments

Replacing/Adjustment of Suspenders

To replace the existing suspenders in order to install a new one, the clamps at the top cable and I or J bolt

at the bottom shall be opened, the entire suspender properly dismantled, and a new one fitted exactly at the required place. While replacing or adjusting the suspenders the verticality of the suspender as well as the clear span between two suspenders shall be maintained.

Replacing/Adjustment of Cross Beams

The replacement and/or adjustment of the cross beam shall be done as defined by the design. Adjacent walkway elements of the beam which has to be replaced or adjusted shall be opened, the beam then shall be adjusted or replaced with a new one. The hook connecting the beam with the suspender shall be properly fitted so as to control the beam-to-beam distance, verticality of suspenders, and the alignment (parallel) of the beams themselves so that the standard pieces of the steel walkway deck fits in properly.

Dismantling/Refining of the Walkway

In case of maintenance of the walkway or replacing the wooden walkway with a new steel deck the entire walkway shall be dismantled. Existing walkway planks, nailing strips, and the cross flats shall be dismantled carefully. The remaining cross beam shall be adjusted, cleaned and painted as designed. New walkway, either wooden or steel deck, shall be properly fixed as per the design. This is equivalent to initial walkway fitting. This shall include removal of old nuts and bolts of wooden deck to be dismantled.

Dismantling/Replacement of Wire mesh Netting

Useless wire mesh netting shall be opened, unrolled and removed from the bridge walkway area. New wire mesh shall be properly fixed by using binding wire which shall be woven along the wire mesh and handrail/fixation cable. The wire mesh net has to be folded around the handrail cable.

(5) Finishing Works

For retightening of bulldog grips, nuts, etc.; coal tar application; and repainting of steel parts, a reference shall be made to item No 2408. However, because of difficulty painting surfaces without any access at site, it shall be done as mentioned in specific specification regarding maintenance of bridges.

(a) Rust Prevention by Repainting

Surface to be painted or otherwise treated shall be dry, thoroughly cleaned and free from oil, grease and swarf removed properly by degreasing agents. Surfaces accessible to mechanical power tool operation shall be cleaned by employing power-operated wire brushes and inaccessible surfaces shall be cleaned by hand scraping, wire brushing, and by using coarse sandpaper, steel wool and emery paper.

Cleaned surfaces shall have a light metallic luster. Inaccessible surfaces except the interior of sealed hollow structures shall receive the full protective treatment before assembly. Painting shall not be done prior to welding. Welds and adjacent parent metal shall not be painted prior to de-slagging. Parts to be encased in concrete shall not be painted or oiled (refer to standard drawing and steel parts lists to identify such parts).

Two base coats of "red lead primer" or “red oxide zinc chromate primer” and two finishing coats of "polyurethane" enamel paint has to be applied with the first base coat applied not more than 5 hours after cleaning of the parts. The minimum thickness of all 4 coats together shall not be less than 0.12 mm. The first base coat has to be applied with brush or roller by hand. Between the two applications of the base coats, a time span of at least 3 days has to be maintained.

Polyurethane enamel should be sky blue.

(6) Other Miscellaneous

River Diversion:

During construction of structures in or adjacent to the riverbed, the Contractor will have to control the river and divert it by constructing necessary cofferdams, channels, flumes, drains, sumps and any other temporary protective work according to the design.

Approach Trails:

The extension of existing trails or construction of new trails shall be executed at the locations indicated on the drawings. Trail width will normally be 2.0 m but not less than 1.5m. Appropriate measures shall be taken to protect the trails from erosion.

Quarries and Spoil Dumps:

Any quarry operated as part of this Contract shall be maintained and left in a stable condition without steep slopes and be either refilled or drained and be landscaped by appropriate planting. Rock or gravel taken from a river shall be removed over some distance so as to limit the depth of material removed at any one location, not disrupt the river flow or damage or undermine the riverbanks.

The Contractor shall not deposit excavated material on land in Government or private ownership except as directed by the Project Manager in writing or by permission in writing of the authority responsible for such land in Government ownership, or of the owner or responsible representative of the owner of such land in private ownership, and only then in those places and under such conditions as the authority, owner or responsible representative may prescribe.

Safety, Security and Protection of the Environment:

The Contractor shall, throughout the execution and completion of the works and the remedying of any defects therein:

Have full regard for the safety of workers by providing safety boots, jackets, helmets, gloves etc as directed by site in charge/Project Manager.

Keep all persons entitled to be upon the site and keep the site (so as the same is under his control) and the works (so far as the same are not completed or occupied by the Employer) in an orderly state appropriate to the avoidance of danger to such persons.

Provide and maintain at his own cost all lights, guards, fencing, warning signs and watching, when necessary or required by the Project Manager or by any duly constituted authority, for the protection of the Works or for the safety and convenience of the public and others.

Take all reasonable steps to protect the environment on and off the site and to avoid damage or nuisance to persons or to property of the public or others resulting from pollution, noise or other causes arising as a consequence of his methods of operation.

Ensure that any cut or fill slopes are planted in grass or other plant cover as soon as possible to protect them from erosion.

Any spoil or material removed from excavation shall be disposed off to designated stable tipping areas as directed by the Project Manager.

Fuel-wood shall not be used as a means of heating during the processing or preparation of any materials forming part of the works.

The Project Manager shall have the power to disallow any working practice or activity of the Contractor or direct that such practices or activities be modified should the Project Manager consider, on the advice of the relevant Government Departments, that the practices or activities will be harmful to wildlife.

Provide on the Site such lifesaving apparatus as may be appropriate and an adequate and easily accessible first aid outfit or such outfits as may be required by any government ordinance, factory act, etc., subsequently published and amended from time to time.

2413 MEASUREMENT

Unless stated otherwise, all items of works specified shall be measured in their respective units as specified in the Bill of Quantities of the contract.

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2414 PAYMENT

All bridge-related work shall be paid as per the respective contract unit rate. The Contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

SECTION 2500: MISCELLANEOUS WORKS

2501 SCOPE 25-1

2502 RAILINGS 25-1

2503 WEEP HOLES WITH DRY GRADED STONES 25-1

2504 MILD STEEL TRASH RACK 25-3

2505 RUBBER SEAL 25-3

2506 BITUMINOUS BOARD 25-4

2507 STEEL SHEET PILE 25-4

2508 MICROPILING WORKS 25-5

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2501SCOPE

This Section cover the works related to the construction of miscellaneous works such as precast members for railings, rubber seal, and bituminous board on drainage structure, trash rack in canal or dam, weep holes, sheet piles and micro piling works. These miscellaneous works are to be constructed in connection with the structures related to irrigation and drainage.

2502 RAILINGS

(1) General

(a) Railing includes the portion of the structure erected on and above the kerb or slab for the protection of pedestrians and traffic as shown on the Drawing.

(b) Railings shall not be constructed until the false work for the span has been released. For concrete with steel reinforcement, specifications of the items of concrete and reinforcement mentioned under relevant Sections of these Specifications shall be applicable.

(c) Railing shall be carefully erected true to line and grade. Posts shall be vertical with a tolerance not exceeding 0.2%. The pockets left for posts shall be filled up with the concrete of the same grade as the post.

(d) The type of railing to be constructed shall be as shown on the Drawing.

(e) Expansion joint in the railings shall be maintained to ensure proper functioningof the joint.

(2) Pre-cast Concrete Railings

Pre-cast members for railings shall be of reinforced cement concrete and shall conform to the specifications given in Section 800. The maximum size of the aggregate shall be limited to 12 mm and the concrete grade shall be M30. The pre-cast members shall be removed from the moulds as soon as practicable and shall be kept damp for a period of at least 10 days. During this period, they shall be protected from sun and wind. Any pre-cast member that becomes chipped, marred or cracked before or during the process of placing shall be rejected. Care shall be taken to watch the surface of the cast-in-situ portion of the deck. Railing shall be erected to the true line and grade with a tolerance of vertical post not exceeding 0.2% (1 in 500) in anyone panel.

(3) Measurement

Railings shall be measured in linear meter from end to end along the face of railing installed including end and intermediate post with no deduction for gap as shown in Drawing. Unless otherwise specified, individual pipe element of railing members, posts, bolts, nuts, fittings etc. shall not be measured.

(4) Payment

Railing, measured as above, shall be paid at the contract unit rate. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

2503 WEEP HOLES WITH DRY GRADED STONES

(1) General

Weep holes shall be provided in solid plain concrete/reinforced concrete, brick/stone masonry, abutment, wing wall, return walls or other structures as shown on the Drawing or as directed by the Engineer.

(2) Materials

Filter materials shall be either gravel with geo-textile/geo-membrane or appropriately graded gravel material as shown on the Drawing or directed by the Engineer.

Where geo-textile/geo-membrane is provided or shown on the Drawing, the filter material shall consist of

gravel. It shall conform to the grading limits set out in Table 25.1.

Table 26.1: Filter Material Grading Limits

Sieve Size (mm)	Percentage Passing by Weight
63	100
37.5	85-100
20	0-20
10	0-5
0.075	-

Geotextile shall comply with Section 1500. Geo membrane shall comply with Sub-clause 1507.

Where no geotextile/geo membrane are provided or shown on the Drawing, the grading curve required for filter material shall be determined for each site. Grading criteria requirement for both underlying and overlying material shall be fulfilled. The criteria shall be as follows:

a) $\frac{\text{d15\% filter}}{\text{d85\% subsoil}} < 5$ b) $\frac{\text{d50\% filter}}{\text{d50\% subsoil}} < 25$

c) $4 < \frac{\text{d15\% filter}}{\text{d15\% subsoil}} < 20$

Where, d15% designates the 15% size of the material (i.e. the size of the sieve that allows 15% by weight of the material to pass through it).

Similarly, d50% and d85% designate the sizes of sieve that allow 50% and 85% respectively by weight of the material to pass through it.

Alternatively, drainage composite shall be designed as per Table 15.16

Drainage composite consisting of a polypropylene extruded mat core with a nonwoven geotextile filter on one/both sides can be used as an advanced alternative technical solution for drainage purposes. The filters shall be fully bonded to the mat by means of thermal treatment only (glues or other systems who could alter the hydraulic performances of the filter shall not be acceptable).

The core mat shall be manufactured by extruding monofilament of polypropylene to obtain a uniform channel-like structure to provide planar water flow.

(3) Construction

Surfaces receiving geo-textile/geo-membrane shall be free of loose or extraneous materials and sharp objects. Geo-textile/Geo-membrane shall be placed in accordance with the producer's instructions or as instructed by the Engineer. The minimum overlapping shall be 450 mm. If jointed in longitudinal direction by sewing or gluing, the joint shall have the same strength as the fabric itself.

The filter material shall be compacted layer by layer to a minimum density of 93% of the MDD (Heavy Compaction).

(4) Tests and Standard of Acceptance

Copies of manufacturer's certificate for geo-textile/geo-membrane to be used shall be furnished by the Contractor. In addition, the Engineer may ask for testing in independent laboratories. All test results shall meet the specified requirements.

Minimum one set of tests for gradation and compaction of filter material shall be executed for every 50 cu.m and every change in source of material. The results shall meet the specified requirements.

(5) Measurement

Unless otherwise stated, Geo-textile/ Drainage composite/Geo-membrane shall be measured in square meter. Overlapping shall not be measured for payment. Filter material shall be measured in cubic meter.

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(6) Payment

Geo-textile/Geo-membrane/ drainage composite and filter material measured as provided above shall be paid the respective contract unit rates which shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specification.

2504 MILD STEEL TRASH RACK

(1) General

The Contractor shall furnish and install trash racks as specified in the contract or on the drawing at the entrance of intakes of Canal Siphon, Drainage Siphon, Dam, etc to protect the entry of objectionably large debris.

(2) Materials

The design of trash rack shall be complying with requirements of IS 11388-2012. A trash rack shall consist of a rack panel and supporting member to be embedded into the concrete base. Rack panels shall be fabricated of steel frames and flat and round steel bars and be fixed onto supporting members anchored in the base concrete by corrosion-resisting steel bolt fittings, as shown on the Drawings. Supporting members at floor and horizontal beams, if any, shall be anchored to the concrete base rigidly. All materials used for trash racks shall comply with IS 800 or IS 2062.

The trash rack shall be installed as shown on the Drawings or as directed by the Engineer. After complete installation, the trash rack shall be thoroughly painted, and the painting shall in all respects conform to the requirements of Painting of gate works as specified in Section 2000 or IS 11388-2012 and should be acceptable to the Engineer.

(3) Measurement and Payment

Measurement for payment for trash racks shall be made for the design weight of the structural steel members actually used in accordance with the Drawing, or as directed by the Engineer. Clips, ties or other materials used for positioning and fastening each member of the fabricated parts in place, and such small hardware as nuts, washers, hinges, hook for lock, etc. shall not be measured separately for payment as cost of such items shall be deemed to be included in the item rate.

Payment for furnishing, handling, assembling, transporting, installing and finishing a trash rack, shall be made at the contract unit rate in the Bill of Quantities. The unit rate shall include all costs of labour, materials and equipment, including the cost of painting and furnishing all required hardware and others necessary items. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

2505 RUBBER SEAL

(1) General

This section lays down the specification for rubber seals used for all common types of hydraulic gates and their joints and for construction and expansion joints.

(2) Materials

The basic polymer shall be natural rubber, or a co-polymer of butadiene and styrene, or a blend of both and the compound shall contain not less than 70 percent, by volume, of the basic polymer and the remainder shall consist of reinforcing carbon black, zinc oxide, accelerators, antioxidants, vulcanizing agents and plasticizers. Rubber seals may be cladded by fluorocarbon or Teflon to reduce frictional force.

The compound shall have the physical properties complying with IS 15466:2004. The tolerance on sectional dimension of all seals shall be ± 0.5 percent, however tolerance shall not apply to the thickness of cladding film, normal thickness of cladding should not be less than 1 mm.

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(3) Tests and Standard of Acceptance

The additional test and requirements for rubber seal shall comply with IS 15466:2004. The results shall meet the specified requirements.

(4) Measurement and Payment

Providing, fitting and fixing of rubber seal shall be measured in linear meter used in accordance with the Drawing, or as directed by the Engineer.

Payment for providing, fitting and fixing of rubber seal shall be made at the contract unit rate in Bill of Quantities. The unit rate shall include all costs of labour, materials and equipment required for the work. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

2506 BITUMINOUS BOARD

(1) General

This section lays down the specification for bituminous boards (bitumen impregnated fiber fillers) used for filling expansion and construction joints in concrete structures.

(2) Materials

Bituminous board shall be of Shalitex or equivalent conforming to IS: 73-1961 or IS: 702-1961. Fiber shall be either soft board, or fiber board, or cane or any other suitable fiber of cellular nature.

(3) Tests and Standard of Acceptance

The length, width and thickness of the preformed strips shall be as per contract or the specifications when measured in accordance with the method given in IS: 10566-1983.

The tolerances on the average dimensions shall be ±5mm on length, ±3mm on width and ±1.5mm on thickness.

(4) Measurement and Payment

Providing and fixing of bituminous board shall be measured in square meter in accordance with the Drawing, or as directed by the Engineer.

Payment for providing and fixing of bituminous board shall be made at the contract unit rate in Bill of Quantities. The unit rate shall include all costs of labour, materials and equipment required for the work. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

2507 STEEL SHEET PILE

(1) General

Steel sheet piles are sections of steel materials with interlocking edges that are driven into the ground as cutoff structure in hydraulic structure to increase the creep length or to provide earth retention and excavation support. Sheet piles are most commonly made of steel, but can also be formed of timber or reinforced concrete. They are installed in sequence to design depth along the planned alignment. The interlocked sheet piles form a wall for permanent or temporary lateral earth support with reduced groundwater inflow. Steel is the most common form of sheet piles as it has good resistance to high driving stresses, excellent water-tightness, and can be increased in length either by welding or bolting. Steel sheet piles are available in different sections such as U-section, Z- Section, Trapezoidal section, etc.

(2) Materials

Steel Surface sheet shall not show any defects under use. The steel sheet pile shall conform to IS: 2314-

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2023. The steel shall have 0.2 to 0.35 percent copper to provide corrosion resistance.

(3) Dimensions and Tolerance

Profile and nominal dimensions of different steel piling sections shall be as per figure and tables in IS: 2314-2023. Tolerance for width, height and thickness of Z-type, U-type and flat-type steel sheet piling sections shall be as given in Table 5 of IS: 2314-2023.

The interlocks shall fit with adequate free play so that the piles can easily be fitted into each other, and shall be so designed that the piles are firmly engaged despite the free play. The tolerance over the design dimension (inter locks) shall be as given in Table 6 of IS: 2314-2023. Tolerance on the mass shall be + 4 percent and -2.5 percent.

(4) Measurement and Payment

Providing and driving Steel Sheet Pile on specified alignment including Painting shall be measured in Metric Tonne or linear meter as specified in the contract or on the Drawing.

Payment for providing and driving Steel Sheet Pile shall be made at the contract unit rate in the Bill of Quantities. The unit rate shall include all costs of labour, materials, painting, driving and equipment required for the work. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.

2508 MICROPILING WORKS

(1) Scope

The Contractor shall supply, install and test micro piles shown on the drawings or specified in the contract in accordance with this specification. The Contractor shall allow for all necessary operations including cutting through concrete slabs, scaffolding, platforms, handling equipment, tools machinery etc necessary for the expeditious handling of the work.

The contract shall be responsible for all labor, materials, tools, plant etc necessary for the following work:

a. Supply and installation of pile foundations to carry the loads as specified in the drawings.

b. Stripping and cutting the piles to cut off levels specified and preparation of the pile head as shown.

c. Carrying out standards load test as specified.

(2) General

The micro pile, also known as root pile, is a small diameter (50 mm to 300 mm) cast-in-situ bored pile formed by cement grout injection and subsequently equipped with permanent steel reinforcement element. The boring is performed with compressed air or by means of a supporting drilling fluid (water, cement grout, bentonite).

(3) Setting out

The Contractor shall be required to employ an approved Licensed Surveyor who will set up the positions of the piles as shown in the pile layout plans of the detailed design. The Contractor will be responsible for the accuracy of location and positioning of each pile. Any errors in setting out and any consequential loss to the Employer will be made good by the Contractor to the satisfaction of the Engineer.

The Contractor shall preserve the pegs set out by the Surveyor. Should any peg be displaced or lost it must be replaced by a Licensed Surveyor to the approval of the Engineer. Upon completion of all piling works, the Contractor shall produce as-built Drawings showing the positions of all piles as installed. The positions of piles shall be verified by a Licensed Surveyor.

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(4) Tolerances

Position

The pile heads shall be positioned as shown on the Drawings within a maximum deviation of 40mm in either direction from correct center point.

Verticality

For bored cast-in-situ piles, the maximum permitted deviation of the finished pile from the vertical at any level is 1 in 150. The contractor shall demonstrate to the satisfaction of Engineer the pile verticality is within the allowable tolerance.

Correction

Should piles be installed outside these tolerances affecting the design and appearance of the structure, the Contractor shall propose and carry out immediate remedial measure to the approval of the Engineer.

(5) Materials

(a) Reinforcement

The type of reinforcement to be used, the diameter shall be as specified in the contract or on the drawing. The reinforcement shall comply with IS 432 (Part 1) or IS 1786 or IS 2062.

(b) Grout

Unless otherwise specified, the grout shall be non-shrink cement grout. The grout mix design such as the water-cement ratio, the minimum cement and grout strength at 7 and 28 days shall be as specified in the specification or on the Drawings. The cement, water and admixture to be used for grouting shall comply with the properties specified in the respective item of the section 800. The quantity of cement per cubic meter of grouting shall not be less than 1 tonne. Water cement ratio shall not be more than 35%. If admixtures are used, details of admixtures shall be submitted to the Engineer for approval before commencement of works. Quantity of admixtures to be used for grouting shall not be less than 1.25% of the weight of cement.

Grout shall be tested in accordance with BS 1881 and BS 4550. Maximum bleed shall be limited to 5%. The use of the admixture shall fully comply with the manufacturer's instructions.

(6) Drilling

(a) Diameter of Piles

The diameter of piles shall not be less than the specified/designed diameter as specified on the drawing at any level throughout its length.

(b) Drilling

The Contractor shall submit to the Engineer details of drilling equipment and drilling procedure for approval before commencement of works. Drilling operations shall be carried out in accordance with the relevant requirements as follows:

i. Boring near recently Cast Piles

Piles shall not be bored next to other piles which have recently been cast less than 24 hours or contain unset grout, whichever longer to avoid damage to any of these piles.

ii. Stability of Drill holes

Contractor shall be fully responsible for maintaining the stability of the sides of boreholes during Micro pile installation and successful completion of the piles. The Contractor shall submit his proposed method of boring the micropiles for approval by the engineer prior to commencement of boring operations.

Irrespective of the presence of ground water, the sides of all borehole shall be kept intact and no loose

material shall be permitted to fall into the bottom of the boreholes. The Contractor's boring equipment shall be able to sink a steel casing to support the sides of all boring.

If the sides of boreholes are found to be unstable, temporary steel casing shall be driven into stable stratum. The borehole shall be filled with drilling fluid to a level sufficiently to stabilize the boreholes.

If ground water is found in any hole in sufficient quantity or gushing out as to affect boring operations or excavations and removal of soil from the boreholes, or the sides of boreholes collapse, then a steel casing of appropriate size and length in conjunction with stabilizing fluid or other alternatives of sufficient strength shall be used to support the sides of the borehole and permit boring operations to proceed smoothly and safely.

The proposed drilling fluid mix must be submitted to the Engineer for approval. Excavations shall not be exposed to the atmosphere longer than is necessary and shall be covered at all times when work is not in progress. Pile excavated shall be casted within 24 hours unless otherwise agreed by the Engineer.

In the event of a rapid loss of drilling fluid from the borehole excavation and caused instability of bore, the excavation shall be backfilled without delay or other appropriate and approved remedial measures taken by the Contractor like installing temporary casing prior to resuming boring at that location. The cost of redrilling of the hole shall be borne by the Contractor.

iii. Stability of bore by Temporary Casing Method

Where the use of a temporary casing is required to maintain the stability of a bore, the bottom of casing shall be kept a minimum of 1 meter or more below the unstable strata to prevent the inflow of soil and the formation of cavities in the surrounding ground.

Temporary casings shall be thin-walled mild steel cylindrical casing. The dimensions and quality of the casing shall be adequate to withstand without damage or distortion all handling, construction and ground stresses to which they will be subjected. The casings shall have an internal diameter not less than the specified pile diameter. They shall be free of significant distortion, of uniform cross-section throughout each continuous length and free from internal projections and encrusted grout which might prevent the proper formation of piles. The joints of casings shall be watertight.

If temporary casings are damaged during installation in a manner which prevents the proper formation of the pile, such casings shall be withdrawn from the bore before grout is placed, repaired if necessary, or other action taken as may be approved to continue the construction of the pile.

iv. Rock Coring

Rock coring shall means coring of sound bedrock. Coring of rock other than two items specified below shall not be considered as coring in rock, and will only be considered as boring in soil.

- Rock socket length
- Cavity roof

Coring of inclined rock surface, limestone pinnacles, cavities and soil below boulder/floater shall be considered as boring in soils.

v. Inspection of Pile Excavation

Where practicable, all pile excavations shall be inspected for their full length before grouting. The Contractor shall provide all the apparatus necessary for the inspection. In the course of inspection any loose or soft material in the borehole which is likely to affect the performance of the pile shall be removed to the satisfaction of the Engineer.

(7) Grouting Operations

(a) Mixing and Placing Grout

The Contractor shall provide details of the method and equipment used in grout mixing. Further information such as grouting pressure, grouting procedure, grouting equipment and technique employed in grouting

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underwater shall also be furnished for approval.

Grout shall be mixed on Site and shall be free from segregation, clumping and bleeding. Grout shall be pumped into its final position in one continuous operation as soon as possible and in no case more than half an hour after mixing.

Micro pile shall be grouted in one continuous process. If there is significant loss of grout, the Contractor may choose to carry out pre-grouting in stages as necessary to prevent further loss of grout for the construction of micro pile. Method statement of pre-grouting including details of equipment, materials and procedures have to be reviewed and approved by the Engineer. If after the process of pre-grouting and re-drilling of the hole is required, the Contractor has to bear the cost and time of the pre-grouting and re-drilling.

(b) Grout Falls

The loss of flushing mediums of either water or drilling mud during drilling will demonstrate potential excessive grout loss or falls. Depending on its seriousness, the Contractor can decide to carry out a water tightness test to decide whether Regrouting is required. The cost and time of the test will be borne by the Contractor. Regrouting and re-drilling shall be carried out if results of the test shown that leakage exceeds 5L/min at an excess head of 0.1 Mpa, measured over a period of 10 minutes.

(8) Construction Of Pile Heads

(a) Lengthening of Piles

Where lengthening is required, the pile reinforcement unit shall be connected on Site to the details shown on the Drawings.

Other means of jointing reinforcement shall be to the approval of the Engineer.

(b) Cutting and Preparation of Pile Heads

Pile heads shall be constructed to the details as shown on the Drawings.

(9) Standards

All materials shall be of the best quality and new. All piling work shall be executed in accordance with the approved designs satisfactory to the Engineer.

(a) Standard Load Tests

Load test of two (2) times the working loads shall be carried out on piles designated by the Engineers and in accordance with BS 8004. The number and location of test piles shall be at the discretion of the Engineer. The Contractor shall submit a detailed proposal of the load tests to the Engineer and shall obtain his approval in writing before carrying them out. On completion of the test, the Contractor shall submit to the engineer the results including graphs showing load and settlement versus time and settlement versus applied load.

(b) Test Report

The report shall contain the following: -

- Pile designation, date completed, weather condition, pile length, pile size, volume of grout intake, time of drilling at intervals not greater than 4meter and time to grout the pile.
- Description of the apparatus used for testing, loading system and procedure for measuring settlement.
- Field data
- Time/Settlement Curve
- Load/Settlement Curve
- Remarks explaining unusual events or data and movement of piles.

- Calibration certificates of dial gauges and pressure gauges.
- The format of record shall be approved by the Engineer.

(10) Damaged Or Displaced Piles

Should the deviation exceed the tolerance provided in this specification, the contractor shall submit this remedial proposal for the approval from the Engineer. Failing this, the faulty pile shall be replaced by additional piles as necessary in positions as determined by the Engineer at no cost to the Employer. The cost of modification to pile cap etc., if any, shall be borne by the Contractor. The same will also apply to any piling work rejected by the Engineer for not truly constructed and installed in accordance with the specification.

Where a pile has been damaged during installation, testing or by other causes, the damaged pile shall be considered and treated as a faulty pile and should be replaced by additional piles as approved by the Engineer at the Contractor's expense.

(11) Measurement

Drilling works on specified alignment to a designed depth shall be measured in meter. And the Cement Grouting works for micro piling shall be measured in cubic metres.

(12) Payment

Payment for drilling works and cement grouting works shall be made at the contract unit rate in the Bill of Quantities. The unit rate shall be deemed to include all costs of labour, materials and equipment required for the work. The contract unit rate shall be the full and the final payment to the Contractor as per Clause 115 to complete the work as per these Specifications.