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# Highway Engineering

Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur

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**Technical and Vocational Stream**
**Learning Resource Material**

# Highway Engineering

**(Grade 10)**
**Civil Engineering**

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# Preface

The curriculum and curricular materials have been developed and revised on a regular basis with the aim of making education objective-oriented, practical, relevant and job oriented. It is necessary to instill the feelings of nationalism, national integrity and democratic spirit in students and equip them with morality, discipline, self-reliance, creativity and thoughtfulness. It is essential to develop linguistic and mathematical skills, knowledge of science, information and communication technology, environment, health and population and life skills in students. It is also necessary to bring the feeling of preserving and promoting arts and aesthetics, humanistic norms, values and ideals. It has become the need of the present time to make them aware of respect for ethnicity, gender, disabilities, languages, religions, cultures, regional diversity, human rights and social values to make them capable of playing the role of responsible citizens with applied technical and vocational knowledge and skills. This learning resource material for civil engineering has been developed in line with the Secondary Level civil engineering Curriculum with an aim to facilitate the students in their study and learning on the subject by incorporating the recommendations and feedback obtained from various schools, workshops, seminars and interaction programs attended by teachers, students, parents and concerned stakeholders.

In bringing out the learning resource material in this form, the contribution of the Director General of CDC Mr. Yubaraj Paudel and members of the subject committee Dr. Jagat Kumar Shrestha, Dr. Bhim Kumar Dahal, Er. Anisha Lamsal, Er. Gita Lamichhane, Mr. Durga Bahadur Pun is highly acknowledged. This learning resource material is compiled and prepared by Er. Jagadishchandra Karki, Er. Kedarnath Dahal, Er. Hemantaraj Joshi and Er. Sabin Silwal. The subject matter of this material is edited by Mr. Badrinath Timsina and Mr. Khilanath Dhamala. Similarly, the language is edited by Mr. Saroj Kumar Mandal. CDC extends sincere thanks to all those who have contributed to developing this material in this form.

This learning resource material contains a wide coverage of subject matters and sample exercises which will help the learners to achieve the competencies and learning outcomes set in the curriculum. Each chapter in the material clearly and concisely deals with the subject matters required for the accomplishment of the learning outcomes. The Curriculum Development Centre always welcomes creative and constructive feedback for the further improvement of the material.

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Curriculum Development Centre
Sanothimi, Bhaktapur

# Table of Content

# Guidelines to Teachers

## A. Facilitation Methods

The goal of this course is to combine the theoretical and practical aspects of the contents needed for the subject. The nature of contents included in this course demands the use of practical or learner focused facilitation processes. Therefore, the practical side of the facilitation process has been focused much. The instructor is expected to design and conduct a variety of practical methods, strategies or techniques which encourage students engage in the process of reflection, sharing, collaboration, exploration and innovation new ideas or learning. For this, the following teaching methods, strategies or techniques are suggested to adopt as per the course content nature and context.

### Brainstorming

Brainstorming is a technique of teaching which is creative thinking process. In this technique, students freely speak or share their ideas on a given topic. The instructor does not judge students' ideas as being right or wrong, but rather encourages them to think and speak creatively and innovatively. In brainstorming time, the instructor expects students to generate their tentative and rough ideas on a given topic which are not judgmental. It is, therefore, brainstorming is free-wheeling, non-judgmental and unstructured in nature. Students or participants are encouraged to freely express their ideas throughout the brainstorming time. Whiteboard and other visual aids can be used to help organize the ideas as they are developed. Following the brainstorming session, concepts are examined and ranked in order of importance, opening the door for more development and execution. Brainstorming is an effective technique for problem-solving, invention, and decision-making because it taps into the group's combined knowledge and creative ideas.

### Demonstration

Demonstration is a practical method of teaching in which the instructor shows or demonstrates the actions, materials, or processes. While demonstrating something the students in the class see, observe, discuss and share ideas on a given topic. Most importantly, abstract and complicated concepts can be presented into visible form through demonstration. Visualization bridges the gap between abstract ideas and concrete manifestations by utilizing the innate human ability to think visually. This enables students to make better decisions, develop their creative potential, and obtain deeper insights across a variety of subject areas.

**Peer Discussion**

Peer conversation is a cooperative process where students converse with their peers to exchange viewpoints, share ideas, and jointly investigate subjects that are relevant or of mutual interest. Peer discussion is an effective teaching strategy used in the classroom to encourage critical thinking, active learning, and knowledge development. Peer discussions encourage students to express their ideas clearly, listen to opposing points of view, and participate in debate or dialogue, all of which contribute to a deeper comprehension and memory of the course material. Peer discussions also help participants develop critical communication and teamwork skills by teaching them how to effectively articulate their views, persuasively defend their positions, and constructively respond to criticism.

Peer conversation is essential for professional growth and community building outside of the classroom because it allows practitioners to share best practices, work together, and solve problems as a group. In addition to expanding their knowledge horizon and deepening their understanding, peer discussions help students build lasting relationships and a feeling of community within their peer networks.

**Group Work**

Group work is a technique of teaching where more than two students or participants work together to complete a task, solve a problem or discuss on a given topic collaboratively. Group work is also a cooperative working process where students join and share their perspectives, abilities, and knowledge to take on challenging job or project. Group work in academic contexts promotes active learning, peer teaching, and the development of collaboration and communication skills. Group work helps individuals to do more together than they might individually do or achieve.

**Gallery Walk**

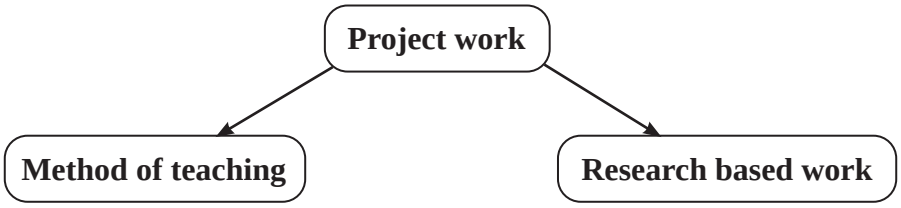
Gallery walk is a critical thinking strategy. It creates interactive learning environment in the classroom. It offers participants or students a structured way to observe exhibition or presentation and also provides opportunity to share ideas. It promotes peer-to-peer or group-to-group engagement by encouraging participants to observe, evaluate and comment on each other's work or ideas. Students who engage in this process improve their communication and critical thinking abilities in addition to their comprehension of the subject matter, which leads to a deeper and more sophisticated investigation of the subjects at hand.

**Interaction**

The dynamic sharing of ideas, knowledge, and experiences between people or things is referred to as interaction, and it frequently takes place in social, academic, or professional settings. It includes a broad range of activities such as dialogue, collaboration or team work, negotiation, problem solving, etc. Mutual understanding, knowledge sharing, and interpersonal relationships are all facilitated by effective interaction. Interaction is essential for building relationships, encouraging learning, and stimulating creativity in both in-person and virtual contexts. Students can broaden their viewpoints, hone their abilities, and jointly achieve solutions to difficult problems by actively interacting with others.

**Project Work**

Project work is a special kind of work that consists of a problematic situation which requires systematic investigation to explore innovative ideas and solutions. Project work can be used in two senses. First, it is a method of teaching in regular class. The next is: it is a research work that requires planned investigation to explore something new. This concept can be presented in the following figure.




Project work entails individuals or teams working together to achieve particular educational objectives. It consists of a number of organized tasks, activities, and deliverables. The end product is important for project work. Generally, project work will be carried out in three stages. They are:

- Planning
- Investigation
- Reporting

**B. Instructional Materials**

Instructional materials are the tools and resources that teachers use to help students. These resources/materials engage students, strengthen learning, and improve conceptual comprehension while supporting the educational goals of a course or program. Different learning styles and preferences can be accommodated by the variety of instructional

resources available. Here are a few examples of typical educational resource types:

- Daily used materials
- Related Pictures
- Reference books
- **Slides and Presentation:** PowerPoint slides, keynote presentations, or other visual aids that help convey information in a visually appealing and organized manner.
- **Audiovisual Materials:** Videos, animations, podcasts, and other multimedia resources that bring concepts to life and cater to auditory and visual learners.
- **Online Resources:** Websites, online articles, e-books, and other web-based materials that can be accessed for further reading and research.

**Maps, Charts, and Graphs:** Visual representations that help learners understand relationships, patterns, and trends in different subjects.

**Real-life Examples and Case Studies:** Stories, examples, or case studies that illustrate the practical application of theoretical concepts and principles.

## C. Assessment

### Formative Test

**Classroom discussions:** Engage students in discussions to assess their understanding of concepts.
**Quizzes and polls:** Use short quizzes or polls to check comprehension during or after a lesson.
**Homework exercises:** Assign tasks that provide ongoing feedback on individual progress.
**Peer review:** Have students review and provide feedback on each other's work.

### Summative Test

**Exams:** Conduct comprehensive exams at the end of a unit or semester.
**Final projects:** Assign projects that demonstrate overall understanding of the subject.

### Peer Assessment

**Group projects:** Evaluate individual contributions within a group project.
**Peer feedback forms:** Provide structured forms for students to assess their peers.
**Classroom presentations:** Have students assess each other's presentations.

**Objective Test**

**Multiple-choice tests:** Use multiple-choice questions to assess knowledge.
**True/False questions:** Assess factual understanding with true/false questions.
**Matching exercises:** Evaluate associations between concepts or terms.

**Portfolio Assessment**

**Compilation of work:** Collect and assess a variety of student work samples.
**Reflection statements:** Ask students to write reflective statements about their work.
**Showcase events:** Organize events where students present their portfolios to peers or instructors.

**Observational Assessment**

**Classroom observations:** Observe students' behavior and engagement during class.
**Performance observations:** Assess practical skills through direct observation.
**Field trips:** Evaluate students' ability to apply knowledge in real-world settings.

# Unit 1 : Introduction

## 1.1. Transportation

1.1 Different modes of transportation:

The hierarchical diagram is shown below generally consisting of two modes:

1. **Primary Modes of Transportation**
2. **Secondary Modes Transportation**

**1. Primary Modes of Transportation**

**Primary Modes :** of transportation include

**Highways:** The highway system consists great accessibility mainly good door to door access with low travel time. The major concern for this mode is environmental pollution. Examples include road, street, highway, etc. (for example : bus, car, truck etc.)

**Waterways:** Waterway provides limited access or has nearly zero door-to-door accessibility. Investments or capital in large ships and boats are quite high, however the operating cost is quite low. Examples include rivers, lakes, seas, oceans for example :ship, boats etc.

**Railways:** Its accessibility is similar to roadway but more standardrized and efficient for longterm use. Examples include rails, train, containers.

**Airways:** The main feature of this mode is its high speed. But it is the costliest mode of transportation and consumes more fuel and vast engineering for modeling. Examples includes air routes (for example: aircrafts, plane, helicopters, etc.)

**Space ways:** This type of transportation is generally used for exploration of planets and satellites in the universe. Examples include space routes (for example: satellite, rockets etc.)

**2. Secondary Modes of Transportation**

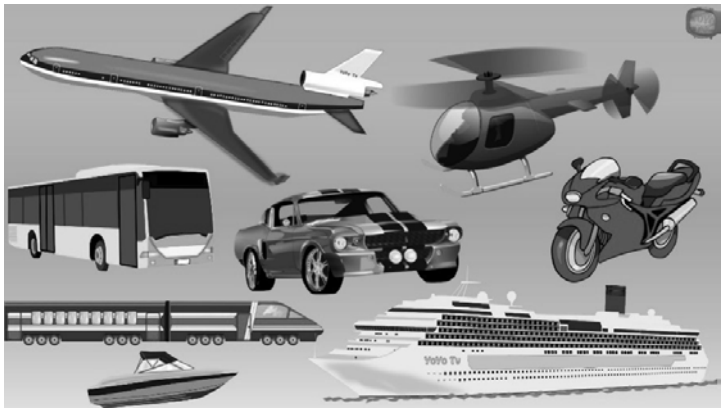
Secondary modes of transportation include:

**Ropeways:** Various types of chain and cable.

**Pipeline:** It is secondary mode of transportation and generally required for transportation of oil and petroleum products. Operating costs are quite low once installed. Examples includes water, gases, sewer pipes etc.

**Canals:** Examples include irrigation canals, power canals, etc.

**Belt Conveyers**



## 1.2 Benefits of Roads

**a. Wide Geographical Coverage**

Other facilities like railway, airway, water way has only an influence over their respective stations. In contrast, roads can be constructed to penetrate the interior of any region and to connect remote villages. Hence, it has wide geographical coverage.

**b. Large Influential Area**

Development of other modes of transportation like railways and airports benefits only around the station and airport. Business promotion and other commercial activities promoted along the roadside, increases the life standards of many people.

**c. Low Capital Investment**

Roads can be constructed with comparatively lower initial cost. Stage construction is feasible for roads.

**d. Door-to-Door Service**

Roads are only modes of transportation which offers door to door service unlike railways and airways.

**e. Flexibility**

Road transport offers the most flexible service, free from fixed schedules. One can use it at any time according to his/her wish. But other services like railways and airways have fixed schedule and one can't travel according to his wish and time. Moreover, the number of vehicles can be adjusted (reduced or increased) according to the public demand.

**f. Highest Employment Potential**

Road transportation has employment potential during and after its constructions thus helping to reduce the unemployment problems.

**g. Personalized Travel and Service**

Road transportation is most feasible for personal travelling since road transportation can be used by people with their own schedule and time. By this means, travel by personal vehicle according to person's own schedule is possible which is not possible by airways and railways.

**h. Economical**

Road transportation is the only economical means of travel for short distance.

**i. Safety**

Road accidents are less dangerous than railways or air accidents.

Hence it is safer.

**j. Low Cost of Packing**

Road transportation involves very low cost of handling and packing. This mode of transportation doesn't require any specifics for handling and packing does not involve high costs.

**k. Quick and Fixed Deliveries**

Road transport offers deliveries for sure and more quickly within the specified period. other means of transport includes long time, highcost and has problems in loading and unloading. Thus, road transport is more feasible in case of deliveries.

## 1.3 Importance of Roads for Nepal

The world has become smaller due to the advanced means of transport and communication available in modern time. You can travel a great distance within

a short time, and you can make contact with anybody in any part of the world immediately. Every day you are using various means of transport directly or indirectly. Probably many of you and your teachers use vehicles to come to school and go home daily. Imagine how you would feel if all the means of transport in your area come to a sudden halt! Or remember how economic and social aspects of a daily life are affected by a transport strike.

A good system of the transport network is needed for a country s economic and social growth. Industries get their raw materials and agricultural as well as finished goods get markets. Tourists can visit places of interest. Trade and business can flourish. Local products find a market. Human relations and cooperation are widened. But the lack of transport makes all these activities difficult, and the overall socio-economic development is obstructed.

In Nepal, where rugged mountainous terrain isolates millions of people from life-saving health care, markets and education, experts say the country s roads are in sore need of more focus and investment.

Transportation costs are the most significant factor for food prices in the mountains, and road access the primary determinant of those costs. Furthermore, food wasted in transit due to lack of roads, or poor-quality ones, can impact the market value of agriculture products. Due to the lack, or poor quality, of roads in rural Nepal, maternal healthcare facilities may be more than a day s walk away which, practitioners say, can be deadly. Research has shown that roads benefit farmers by slashing transportation Research has shown that roads benefit farmers by slashing transportation and farm-to-market time periods, meaning that with less food wasted during transit, more can be sold at market. The World Bank and UN Food and Agriculture Organization have identified well-constructed and well-maintained roads as a crucial aspect of creating an enabling public environment for development and a safeguard against food wasting.

## 1.4 Road Classification According to Nepal Roat Standard 2070

Roads in Nepal are classified as follows:

### A. Administrative Classification

Administrative classification of roads is intended for assigning national importance and level of government responsible for overall management and methods of

financing. According to this classification road are classified into:

**a. National Highways**

**b. Feeder Roads**

**c. District Roads and**

**d. Urban Roads**

**a. National Highways**

National highways are main roads connecting east to west and north to south of the nation. These roads are spread around greater portion of the longer distance travel and have higher level of service in terms of travel speeds and helps in inter-state mobility. These roads are the main routes passing through the length and breadth of the country.

**b. Feeder Roads**

Feeder roads are local roads which help connect small areas but serve a wider scope since it connects district headquarters, major economic centers, tourism centers to National Highways or other feeder roads.

**c. District Roads**

District Roads are important roads within a district serving areas of production and markets and connecting with each other or with the main highways.

**d. Urban Roads**

Urban Roads are the roads serving within the main cities and urban areas or municipality.

**B. Technical/Functional Classification**

For assigning various geometric and technical parameters for design, roads are categorized into classes as follows:

**Class – I**

Class I roads are the highest standard roads with divided carriageway and access control with average daily traffic- ADT of 20,000 passenger care unit- PCU or more in 20 yrs perspective period.

Design speed adopted for design of this class of roads in plain terrain is 120 km/h.

**Class II**

Class II roads are those with average daily traffic- ADT of 5000-20000 passenger care unit- PCU in 20 yrs perspective period.

Design speed adopted for design of this class of roads in plain terrain is 100 km/h.

**Class I II**

Class III roads are those with average daily traffic- ADT of 2000-5000 passenger care unit- PCU in 20 yrs perspective period.

Design speed adopted for design of this class of roads in plain terrain is 80 km/h

**Class I V**

Class IV roads are those with average daily traffic- ADT of less than 2000 passenger care unit- PCU in 20 yrs perspective period. Design speed for this type of roads is 60kmph.

## 1.5 Role of Roads in Rural Development

**Improvement in Transportation Services:** which leads to improved access to market centers for the rural producers, better availability of farm inputs at reduced prices.

**Diversification of Agriculture:** improved market access promotes shift in favor of cash crops and commercialization of agricultural activities.

**Diversification of Live Opportunities:** better connectivity enhances employment opportunities in the non-agricultural sectors.

**Improved Services:** improved road connectivity, inter-alia, enhances access to education, health and financial services.

**Increase in the Outreach of the State:** improved rural roads facilitate better availability of public services and functionaries in rural areas.

## 1.6 History of Development of Roads

1. **Early Development**

   The first mode of travel was on the foot tracks. These kinds of roads were developed for different purposes like seeking for food, water, hunting etc. The next major mode of transport was animals. Animals were used to transport

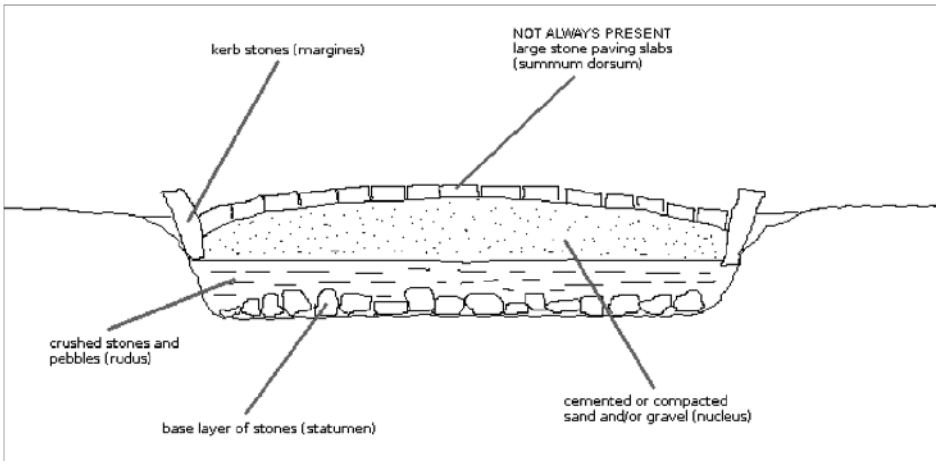
mean and material. Later, simple animal drawn vehicle was developed, and this became a common and popular mode of transportation for a long period, which brought up the necessity of providing hard surface for this wheeled vehicle to move on. Such hard surface is believed to have existed in mesopotamia around about 3500 B.C.The invention of wheel in Mesopotamian civilization led to the development of animal drawn vehicles. Then it became necessary that the road surface should be capable of carrying greater loads.

## 2. Roman Roads

During the period of the Roman Empire, roads were constructed in large scale. Romans constructed the roads radiating in many directions from Rome, mainly for military operations.

During roman s period many roads were built of stone blocks of considerable thickness.

The main features of the roman roads are they are built straight regardless of gradient and used heavy foundation stones at the bottom.



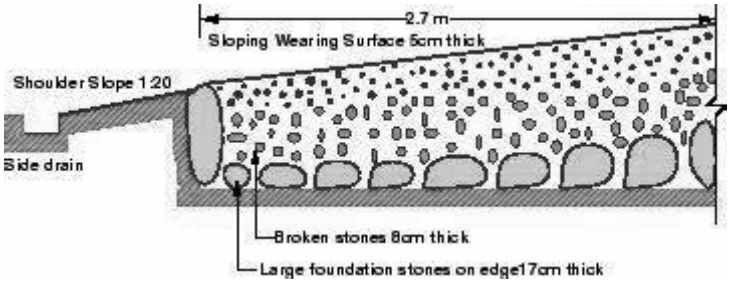

The following are the main features of roman roads:

- They were built straight regardless of gradients.
- The soft soil was excavated and removed till hard stratum was reached.
- The total thickness of construction was 0.75m to 1.2m at some places even though the magnitude of wheel load of animal drawn vehicles was very low.
- Some of these roman roads are still in existence after over 2000 years.

### 3. Tresaguet Construction

Until the eighteen centuries, there is no evidence of any new road construction method except the concept used by romans. Pierre Trezeguet developed an improved method of construction in 1764 AD in France. His construction was much cheaper than the roman roads. The main features of his constructions are:

- The thickness of construction need be only in the order of 30cm. Consideration was given by him to sub-grade moisture condition and drainage of surface water
- The sub-grade was prepared, and a layer of foundation stones were laid on edge by hand. At two edge of pavement large stone were embedded edge wise to serve as submerged kerb stones
- The corners of these heavy foundation stones were hammered and then the interstices filled with smaller stones. Broken stones were packed to a thickness of about 8 cm and compacted
- The top wearing course was made of smaller stones and compacted to a thickness about 5 cm at the edge and gradually increased towards the center, giving a cross slope of 1 in 45 to surface, to provide surface drainage
- The shoulders were also provided with a cross slope to drain surface water to side drain.



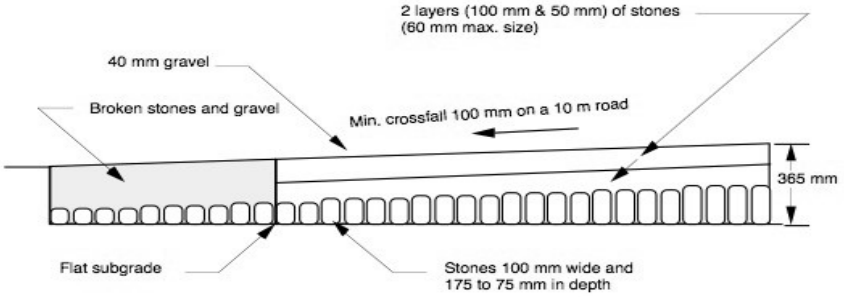

### 4. Telford Construction

Thomas Telford began his work in early 19th century in England. He also believed in using heavy foundation stones above soil sub-grade. He insisted on providing definite cross slope for the top surface of pavement by varying the thickness of foundation stones. The main features of his construction are:

- A level sub-grade was prepared to design width of about 9 meters The stones of lesser thickness (17cm) were placed towards edge and stones of increasing thickness up to 22cm were laid towards the centre such that these stones of

varying thickness provides the cross slope

- The gapes between foundation stones were filled with smaller stones and properly beaten down
- The central portion of about 5.5 meters width was covered with two layers of angular broken stones to compacted thickness of 10 and 5cm.
- A binding layer of wearing course 4cm thick was constructed on top using gravel. The finished surface has a cross slope of about 1 in 45




## 5. Macadam Construction

Johan Macadam, a Scottish road builder is considered as the pioneer of modern road construction. He was the first man to realize the importance of sub-grade drainage in addition to its surface drainage. He was also first person to realize the baseless use of hard and strong stones in road base. The total thickness of the road pavement suggested by him is just 25 cm.

### Construction steps

- Sub-grade is compacted and prepared with a cross-slope of 1 in 36 up to a desired width.
- Broken stones of strong variety, all passing through 5 cm sieve were compacted to a uniform thickness of 10cm.
- A second layer of strong broken stones of sizes 3.75cm was compacted to thickness of 10cm.
- The top layer consisted of stones smaller than 2cm compacted to a thickness of about 5cm and finished so that the cross slopes of pavement was about 1 in 36.

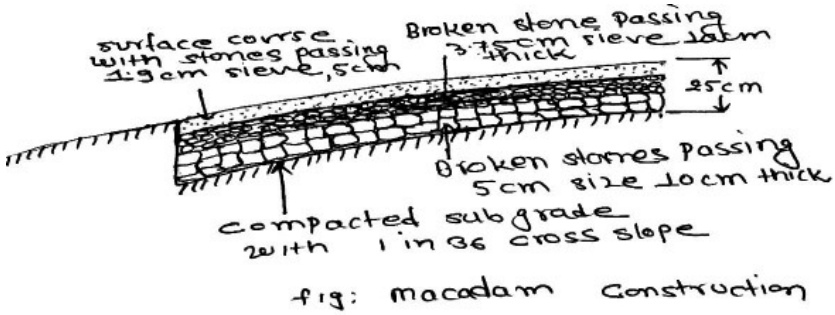



fig: macadam Construction

**Modern Roads**

All of the modern roads are improvements over the macadam construction. Bituminous binders were made use of instead of soil binder in the surface course of road pavements. Apart from flexible pavements with bituminous layers, rigid pavements using cement concrete were also developed.

Some examples of modern roads are:

- Roads with surface dressing. Surface treatments at top with various granular base below
- Bituminous bound macadam road
- Asphalt concrete roads
- Cement concrete roads.

## 1.7 Rural and Urban Roads Advantages and Disadvantages

As we have already discussed the advantages of road transport in (1.2) portion which are also the advantages of urban roads. So, some of the advantages of urban roads are illustrated below.

**Advantages of Rural Roads**

1. The formation width gets stabilized and chance of settlement of the soil due to subsequent heavier traffic loads are reduced
2. Easy for construction of first stage as well as next stage
3. Local people are maximally get maximum engaged in the construction
4. Disputes arise at site can easily be managed
5. Locally available materials are used which reduce cost of construction

**Disadvantages of Road (rural/urban) Transport**

1. During the construction of highways and rural road, many natural resources may be depleted and there may be exploitation of natural environment
2. Road transportation contributes to environmental pollution like air, noise pollution
3. It creates the problem of parking in urban areas
4. Road transport is economical only for short hauls. They are uneconomical for long distance
5. Rate of accident is more than railways and airways in both rural and urban roads, i.e. both rural and urban roads are prone to accidents
6. Road transportation consumes more energy. Loss of valuable land during construction

## 1.8 Types of Feeder Roads and Overview in Construction

**A) Based on use in Different Season**

All weather road

Fair weather road

**B) Based on Carriage Way**

**Paved road:** WBM, Bituminous, concrete road

**Unpaved road:** Earthen Road, Gravel Road

**C) Based on Type of Pavement Surfacing**

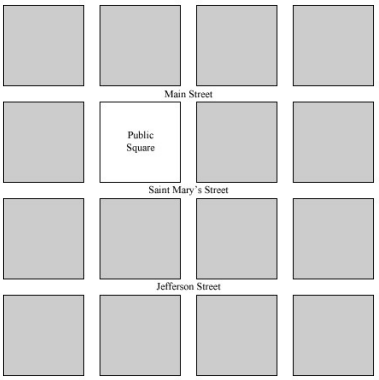
**Surfaced Road:** Provided with bituminous or cement concrete surfacing.

**Unsurfaced Road:** Not provided with bituminous or cement concrete surfacing.

## 1.9 Road Patterns

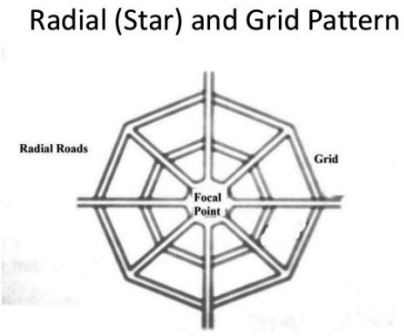
**1) Grid Iron Pattern**

In this pattern, the whole area is divided into rectangular blocks of plots, with streets intersecting at right angles. The main road which passes through the center of the area should be sufficiently wide and other branch roads may be comparatively narrow. The main road is provided a direct approach to outside the city.




**2) Radial or Star and Block Pattern**

In this pattern, the entire area is divided into a network of roads radiating from the business centre outwardly. In between radiating main roads, the built-up area may be planned with rectangular block.



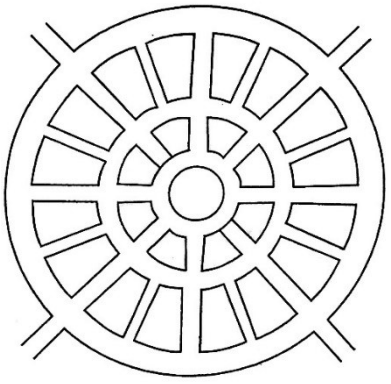



Fig. 12.7. A radial and circular road pattern.

**3) Radial or Star and Circular Pattern**

In this system, the main radial roads radiating from the central business area are connected together with concentric roads. In these areas, bounded by adjacent radial and corresponding circular roads, the built-up area is planned with a curved block system.

**4) Hexagonal Pattern**

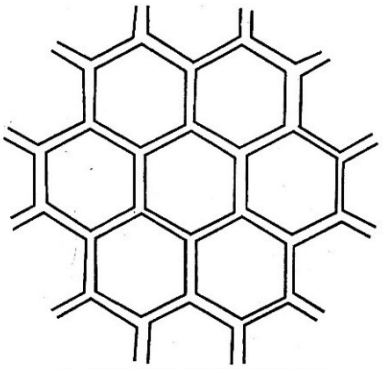


Fig. 12.8. A hexagonal road pattern.

In this type of pattern, the entire area is provided with a network of roads forming hexagonal figures. At each corner of the hexagon, three roads meet. The built-up area boundary by the sides of the hexagons is further divided in suitable sizes.

## Exercise

### Choose the correct answer from the given alternatives.

1. What is the primary purpose of a road?
   a. To support air transportation
   b. To facilitate waterborne trade
   c. To provide safe and efficient land transportation
   d. To serve as a boundary between regions

2. Which of the following is a key factor in determining the design of a road?
   a. Type of vehicles expected to use it
   b. Color of surrounding landscape
   c. Distance from the nearest airport
   d. The average height of buildings nearby

### Write short answer to the following questions.

1. Give the administrative classification of road according to NRS-2070
2. Write down the main features of romans road.
3. What are the disadvantages of road transport?
4. Describe the importance of road in development of nation.
5. Mention any four highways including their length.

### Write long answer to the following questions.

1. What are the advantages and disadvantages of road?
2. What is the classification of road according NRS 2070?
3. Describe the various road patterns in brief with sketch

# Unit 2 : Road Alignment and Survey

**Highway Alignment**

The position or layout of Centre line of highway on ground is called the highway alignment. Highway alignments include both horizontal and vertical alignment of roadway. The horizontal alignment includes straight path, horizontal deviation and curves while vertical alignment includes vertical curves gradients etc.

A new road should be aligned carefully as improper alignment would result following disadvantages.

i. Increase in construction cost
ii. Increase in maintenance cost
iii. Increase in vehicle operation cost
iv. Increase in accident rate

## 2.1 Fundamental Principles of Alignment

**a. Horizontal Alignment Fundamentals:** It has the horizontal control over the alignment. Examples include horizontal curves, superelevation etc.

**b. Vertical Alignment Fundamentals:** It has the vertical control while aligning. examples includes: gradient, crest, vertical curves, sag etc.

## 2.2 Requirements of Road Alignment

**Short:** The distance between two terminal stations should be short and as far as possible while aligning. But due to some practical considerations deviations may be needed. Short alignment can reduce the vehicle operation cost and saves the time.

**Easy:** The alignment should be easy to construct and maintain. It should not be through tough regions like hard, high, hard, steep mountains, slopes and gorges. Also, the alignment should be easy for the operation of vehicles with easy gradients and curves.

**Safe:** Alignment should be safe enough for construction and maintenance from the viewpoint of stability of natural hill slopes, embankment and cut slopes and foundation of embankments. Except that, it should be safe for the traffic operation with safe geometric features.

**Economical:-** Highway alignment should be economical as far as possible. Alignment could be considered economical only, if the total cost including initial cost, maintenance cost and vehicle operation cost is lowest.ie least earthwork, use of locally available materials, least fuel consumption, least wear and tear of vehicle parts, least maintenance cost and maximum use to the population.

**Comfort:** The highway alignment should assure the comfort to the passenger. In the name of maintaining economy its seen that the road is being constructed haphazardly in context of Nepal. So, the road must be aligned taking into consideration of the design speed, sight distances, gradients, curves etc.

## 2.3 Factors which Control the Selection of Alignment

The various factors which control the highway alignment are as follows:

1. Obligatory points
2. Traffic
3. Geometric design
4. Economics
5. Other considerations

**Obligatory points**

Obligatory points may be divided into two categories:

**Point through which Alignments have to Pass**

- **High Cliff:** While there is not any alternative and mountain comes by, we need to construct the tunnel or go round the hill which again depends on site condition, landscape, cost etc.
- **Bridge:** The highway is to be aligned in such a way that approaches the bridge site. As the bridge site approaches the highway, alignment should be checked accordingly.
- **Intermediate Towns:** The alignment should be fixed in such a way that can make a touch with neighboring town, city tourists area so that the flow becomes easier.

- **Industrial Area or Zone:** It must have access to industrial area so that the flow of raw materials becomes easier which merely helps in exporting too.

**Points through which Alignment should not Pass**

Some examples are:

- Marshy places and waterlogged areas
- Historically and archeologically important property
- Restricted zone for defense, national security
- Costly structural elements requiring heavy compensation. Densely populated areas

**Traffic**

The road alignments should be decided based on the requirements of road traffic. It should suit the traffic flow and its volume.

**Geometric Design**

Geometric design such as gradients, radius of curve and sight distance also governs the alignment of highway.

**Economic Factors**

While aligning a new highway, the initial cost; costs of maintenance and vehicle operation cost should be considered. The initial cost of construction can be decreased if high embankments and deep cutting are avoided, and alignment is chosen in manner to balance the cutting and filling.

**Availability of Construction Materials**

It is suitable to pass the alignment where construction material and labors are available. It helps in reducing the cost of overall construction process.

**Based on Stability and Geological Condition**

It should be fixed taking in consideration geologically stable slopes.

**Other Consideration**

Various other factors which govern the highway alignment are drainage consideration, hydrological factors, political consideration and monotony. Vertical alignment which are often guided by drainage consideration. Precautions must be taken while aligning to decrease the number of drainage structures.

Alignment shouldn't cross other countries border or state. A small bend is to be provided in flat areas or terai areas of Nepal. So, to the break the monotony of driver and keep the driver active.

## 2.4 Engineering Survey for Highway Locations

The main four stages of engineering survey are:

1. Map study
2. Reconnaissance
3. Preliminary survey
4. Final location and detailed survey.

### 1. Map study

With the help of topographic map, it is possible to suggest the likely routes of the road. The main features like rivers, hills, valley etc. are shown on these maps. By study of such map, it is possible to have an idea of several possible alternate routes, so that further details of these are studied later site. The probable alignment can be located on map from the following details available from the map.

Alignment avoid valleys should ponds or lake etc.

When the road must cross a row of hills, consider the possibility of crossing through a mountain pass.

Approximate location for the bridge site for crossing rivers, avoiding the bend of river if any.

Thus, from map study the alternate routes can be suggested.

### 2. Reconnaissance

It is a rapid and rough survey. During the survey, the physical characteristics of the areal are inspected and the proposed route is thoroughly examined. it is done without accurate instruments. A field survey party may fairly inspect the land along the purposed alternative routes of the map in field. All details which are not available in the topographic map are collected and noted down. It is done without accurate instruments. Clinometers are used to determine the slopes of the ground.

Details collected reconnaissance survey are as follows.

i) To study the feasibility or practicability of the proposed route

ii) To reduce the number of alternative routes to the minimum to select the best 2 or 3 routes

iii) Source of construction materials, water and location of stone quarries

iv) Number and type of cross drainage structure, maximum flood level and natural ground water level along the probable routes

**3. Preliminary Survey**

It is the large stage study of one or more feasible routes. It consists of running accurate traverse line along the routes already recommended by the reconnaissance survey in order to obtain sufficient data for final location. It is done by using the instruments such as chain, compass, tape, level & theodolite. The main purpose of the preliminary survey is.

- To survey the various alternate alignments purposed after the reconnaissance
- To compare different proposal in the view of requirements of good alignment
- To work out the probable cost of alternative alignment. To finalize the best alignment from all consideration.

**Method of Preliminary Survey**

- Preparation of baseline traverse
- Levelling along base line traverse
- Collecting topographical and other details
- Drainage study and collection of hydrological data
- Soil survey/geological survey
- Material survey
- Determination of final Centre line of road

**4. Final Location and Detail Survey**

- The alignment finalized after the preliminary survey is to be first located on the field by established the Centre line
- This is done accurately by using instruments. The final route selected after the preliminary survey is surveyed and located on the ground
- This is done accurately by using instruments. The final route selected after the preliminary survey is surveyed and located on the ground. During detail survey

following works are performed

- Pegging the Centre line
- Centre line levelling
- Cross section levelling up to desired width Fixation of property lines
- Temporary water course and stream details
- Material site survey
- Special site survey

## Exercise

### Choose the correct answer from the given alternatives.

1. The surveys of highway alignment are completed in how many stages_____

   a. One  b. Two

   c. Three  d. Four

2. The survey in which details are covered roughly but not accurately is called ____

   a. Reconnaissance  b. rough survey

   c. Map study  d. Detailed study

3. The basic requirement of alignment should be _____

   a. Short  b. Easy

   c. Safe  d. Short, easy, safe, comfort and economical

4. The desire lines are prepared for the study of _____

   a. Traffic flow

   b. Origin and destination

   c. Growth of traffic in the future

   d. All of the mentioned

5. The design of the highway should satisfy _____

   a. Structural requirement

   b. Drainage system

   c. Economical

   d. All of the mentioned

### Write short answer to the following questions.

1. What would be the consequences, if highway alignment were not properly selected?
2. Describe preliminary survey of highway alignment in short
3. Describe map study for highway alignment in short
4. What are the obligatory points related to highway alignment?
5. What are the objectives of reconnaissance in engineering surveys?

## Write long answer to the following questions.

1. What are the various requirements of ideal highway alignment?
2. Explain obligatory points. With sketches, discuss how does it controls the alignment
3. Mention the use of map study in engineering surveys for highway location.
4. Explain how the final location and detailed survey of a highway are carried out.
5. Briefly explain the engineering surveys needed for locating a new highway.

# Unit 3 : General Definition of Terms used in Highway Geometric Design

## 3.1 Traffic Volume, Intensity, Lane, Slip Friction

### Traffic Volume

There are many methods of counting the number of vehicles on the road. Volume can be defined as the number of vehicles that passes a point on a highway in a single lane of highway during specific time interval. The volume can be found by counting the number of vehicles N which enter in the given point in a defined time t. V=N/T

### Traffic Intensity

Traffic volume over a certain time interval for 24 hours is traffic intensity in given period. Some of the measures are described below

1. **Average Annual Daily Traffic (AADT) :** The average 24 hbours traffic volume at a given time interval over full year, that is total vehicles in a road in a year/365
2. **Average Annual Weekday Traffic (AAWT):** It is computed by dividing the total weekday traffic volume for the year by the number of weeks in a year.
3. **Annual Daily Traffic (ADT):** It is the average twenty-four hours volume for a specified period of time like a season, a month, a week etc.

### Traffic Lane

The strip of the carriage way occupied by vehicles moving in a single stream along the road, is referred as a traffic lane. The width of traffic lane is a function of width of design vehicles and safety clearance on either side as necessary for safe driving. The minimum required width of traffic lane is 3.75m and 3.5m for single lane roads and multiple lane roads respectively.

### Slip Friction

## 3.2 Typical Cross Sections of Cutting and Filling and Definition of its Elements

- **Cutting:** The process of cutting or loosening and removing the earth including rock from its original site is called cutting.

- **Filling or Embankment:** It is the process of filling the area with soil to the desired place to maintain the grade when the natural ground level is far below the grade line level where road is to be constructed.

Some of the design elements of cutting and filling are:

- Height of fill
- Fill materials
- Settlement of embankment for running of traffic

**Hauling:** The process of transporting the cut materials from the borrow pit to the site for embankment is known as hauling.

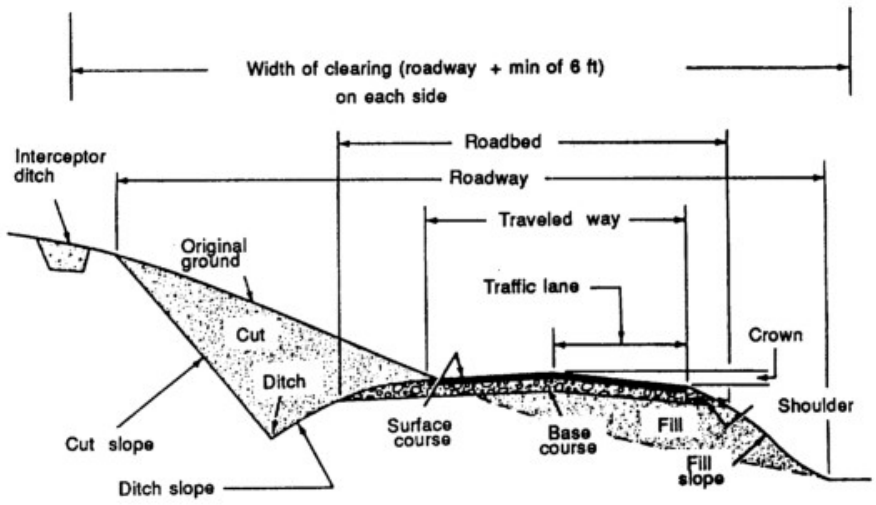
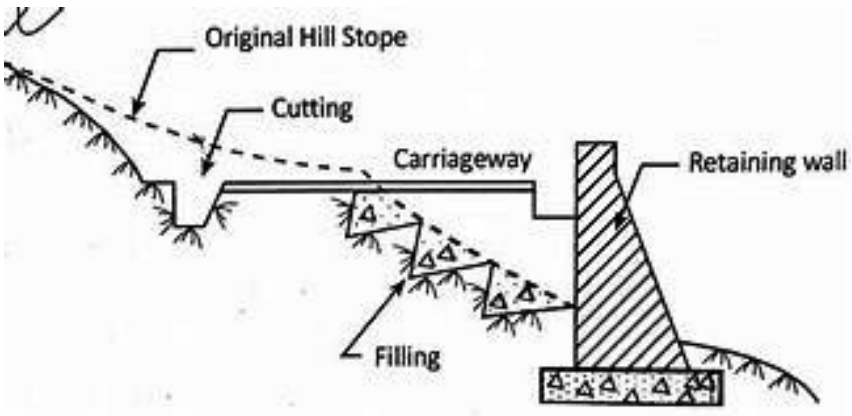



*Figure 9-2. Road cross section and nomenclature*



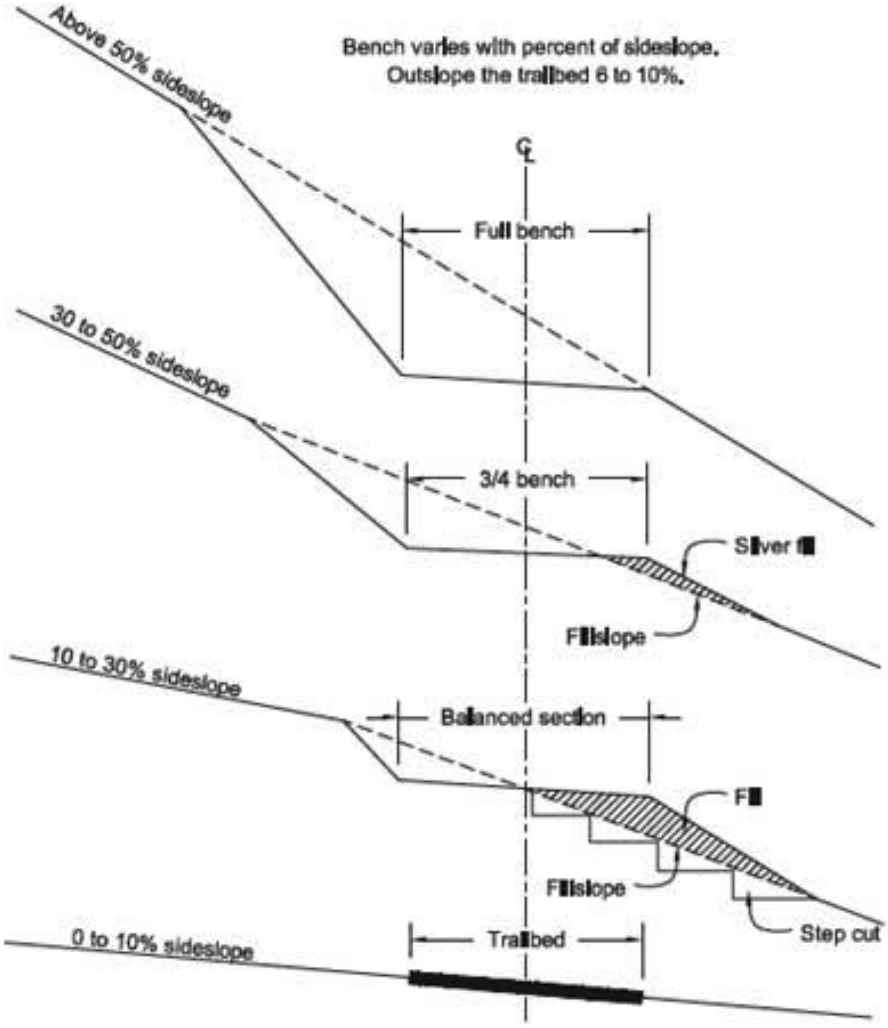



*Fig: c/s showing variations of cutting and filling with different side slopes*

## 3.3 Elements of Cross Section

1. Carriage way
2. Shoulder
3. Roadway
4. Formation width
5. Side slope
6. Laybys
7. Right of way or Land width

8. Camber
9. Super elevation
10. Extra widening

In urban roads, additional elements are:

1. Sidewalk (foot path)
2. Kerb (curb)
3. Median strip

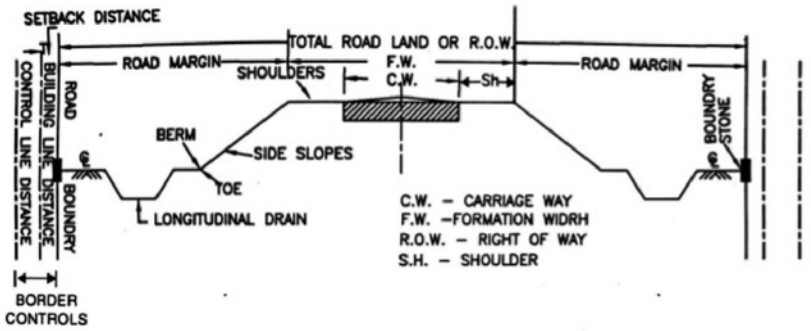



***Fig: Element of cross section of road***

**1. Carriage Way**

A carriage way may be defined as that strip of road which is constructed for the movement of vehicular traffic. It is also called the pavement width. Width of pavement or carriage way is sum of total of the width of traffic lane.

C= n T

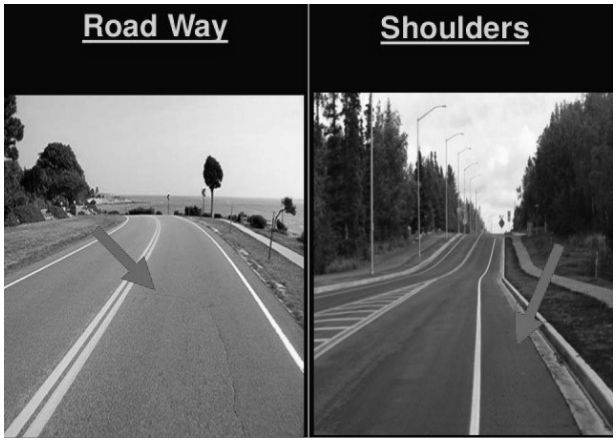
Were,

C= Carriage way width T= Width of lane n = Number of lanes

**2. Shoulder**

Shoulders are the strips, provided on both the sides of carriage way. Shoulders serve as parking places for vehicles which have developed some defect and need parking. If shoulders are not provided, vehicles going out of order shall have to parked on the carriage way and thus efficiency of road is affected.

Shoulder provides lateral stability to the carriageway and also provide a sort of reserve lane for overtaking and crossing in the case of single lane roads. The width of shoulder on either side should be at least 0. 75m.




***The surface of the shoulder may be rougher than the traffic lanes so that vehicles are discouraged to use the shoulder as a regular traffic lane.***

Advantages of the shoulder

- Provide space for parking vehicle
- Provide space for fixing up traffic signals
- Increase the capacity of road by providing frequent opportunities for overtaking.
- Increase the effective width of carriage way
- Improved sight distance with increased lateral clearance

**3. Roadway**

It is that portion of road which is covered by carriage way, shoulder on either side and central strip if any.

**4. Formation Width**

It is the top width of the road embankment or bottom width of road cut measured at finished subgrade level over which carriage way is constructed.

**5. Side Slope**

It is the slope of embankment in case of road in or slope of cutting in case of road in cutting.

**6. Laybys**

Laybys are the intermittent shoulders sufficiently wide and long provided to meet the important function of shoulder where the continuous shoulder on either side cannot be provided from economical consideration.

## 7. Right of Way and Land Width

Right of way is the area of land acquired for the road along its alignment. The width of this acquired land is known as land width or right of way and it depends on the importance of road and possible future development. The right of way should be adequate to accommodate all the elements that make up the cross section of highway and may reasonably provide space for future development. The following are the purposes of right of way,

1. To accommodate drainage facilities
2. To open, side borrow pit
3. To accommodate various road ancillaries
4. To improve visibility in curves
5. To widen the road where required in future with no compensation for property.

According to Nepal Road Standards the right of way of various types of roads is:

| S.N. | Type of Road | Row in meter |
|---|---|---|
| 1. | National highway | 50m (25m on either side from center line of road) |
| 2. | Feeder road | 30m (15m on either side from center line of road) |
| 3. | District road | 20m (10m on either side from center line of road) |

Type of road right of way in meter national highway 50m (25m on either side from center line of road) feeder road 30m (15m on either side from center line of road) district road 20m (10m on either side from center line of road)

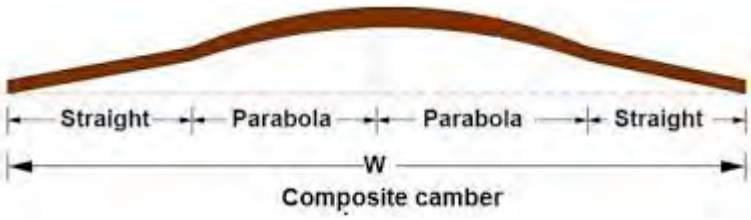
## 8. Camber (cross-slope)

Cross- slope or camber is the slope provided to the road surface in transverse direction to drain off the rainwater from the road surface.

or,

Camber is the convexity provided to the cross section of carriage way. The primary function of a camber is to provide surface drainage.

Usually, the camber is provided on straight roads by raising the Centre of the carriageway with respect to edges, forming crown or highest point along Centre line. Camber can be expressed as a percentage. If camber is X%, cross slope is Xm in 100 m.



Composite camber

Objective of providing camber:

- To drain out surface water
- To prevent infiltration of water into underlying pavement layers and soil subgrade
- To separate the traffic in two directions
- To improve the appearance of road

Required amount of camber on road surface depends on:

- Type of pavement surface
- Amount of rainfall

**Camber to be Provided on Different Road Surface According to NRS 2070,**

**Pavement type Cement Concrete Bituminous Gravel Earthen Camber, %**

| S.N. | Pavement Type | Camber in % |
|---|---|---|
| 1. | Cement Concrete Road | 1.7-2% |
| 2. | Bituminous Road | 2-2.5% |
| 3. | Gravel Road | 4% |
| 4. | Earthen Road | 5% |

**Types of camber**

On the basis of shape following types of camber are generally used

- **Straight line camber:** adopted on flat slope with cement concrete pavement
- **Parabolic camber:** suitable for fast moving Vehicle
- **Composite Camber**

## 9. Super Elevation

When a vehicle negotiates a curve path, it is subjected to an outward force known as centrifugal force. In order to counteract the effect of this centrifugal force and to reduce the tendency of the vehicle to overturn or skid, the outer edge of pavement is raised with respect to inner edge, thus providing a transverse slope throughout the length of horizontal curve. This transverse inclination is called superelevation.

Superelevation is the process of raising outer edge of pavement, with respect to inner along the horizontal curve to counteract the effect of centrifugal force. It is also known as cant or banking.

Superelevation is expressed as the ratio between the difference of heights of outer edge and the inner edge of carriage way and the width of carriageway. Thus, if the carriageway is 15m wide and the level of outer edge is 0.5m above that of inner edge, it would mean a superelevation of 1 in 30.

**Followings are the Advantage of Providing Superelevation**

1. Higher speed without danger of overturning.
2. Maintenance is reduced; otherwise, there will be wear on the outside wheel, causing potholes.
3. The water can be drained of easily.

Maximum value of superelevation shouldn't exceed 7 % Minimum amount of superelevation is to be provided is equal to amount of camber.

## 10. Extra Widening

On horizontal curves, increased carriage way width is provided than the normal width on straight reaches. The increased width of carriage way at horizontal curve is called the extra widening of the pavement. Its value depends upon the sharpness of curve.

**Reasons for Providing Extra Widening on Horizontal Curve**

1. While travelling on a horizontal curve, rare wheels do not trace the same path as front wheel do. This is called the off tracking. In this position more with of the road is occupied by vehicle
2. At more than designed speed if super elevation and lateral friction jointly cannot counteract the centrifugal forcefully, outward slippage of rear wheel may occur, and thus more width of road is covered
3. There is tendency of driver to take outer path of curve to have more sight distance visible ahead
4. The clearance between the vehicles, crossing or passing each other over horizontal curve is kept more than that on a straight road due to psychological effect.

**The Extra Widening on Horizontal Curve is Divided into two Parts**

I. Mechanical widening

II. Psychological widening the amount of extra widening to be provided on horizontal curve is sum of mechanical widening and psychological widening

**Mechanical Widening**

The widening required to account for the off tracking is called mechanical widening. which is given by,

$W=n\ l^2 / 2R$ Where n= Number of lanes

l= length of wheelbase of longest vehicle in m R = Radius of horizontal curve in m

**Psychological Widening**

Value of psychological widening to be provided on horizontal curve is, $WPs=V/ 9.5R$ Where V is designed speed in Km/hr.

**Thus, total widening required on horizontal curve is. $W_e = W_m + W_P$**

**1. Sidewalk**

Sidewalk is that portion of the urban road which is provided for the movement of pedestrian traffic where their intensity is high. Sidewalks are raised to about 15 to 30 cm high from carriage way or separated by laying stone or concrete block to provide safety to pedestrian against fast moving traffic. Width of the footpath depends on the volume of anticipated pedestrian traffic. But a minimum width of 1.5 m is required.

**2. Kerb (Curb)**

Kerb is that element of road, which separates the vehicular traffic from pedestrians by providing physical barriers between them. The face of the kerb may be vertical or slopping and height varies from 15 to 25 cm.

**Function of Kerb**

- To facilitate and control drainage
- To strengthen and protect the pavement edge.
- To present more finished appearance to segregate the traffic lane

### 3. Median Strip

It is the central raised strip within the roadways constructed to separate the traffic moving in one direction from the traffic in opposite direction. The main function of the median strip is to prevent head-on collision between vehicles moving in opposite directions on adjacent lane.

- To separate the opposite streams of traffic.
- To minimize head- on collision between vehicles moving in opposite directions.
- To minimize head-light glare to segregate traffic lane.

## 3.4 Sight Distance Definition and Its Types

**Sight distance** is defined as the length of carriageway that is visible to the driver at any instant from the specified height of drivers' eye above the road surface. The specified height of the drivers' eye is 1.0 and 1.2 m according to Nepal road standars and Indian road congress respectively. The height of object is taken as 0.15m above road surface.

**Restriction to Sight Distance**

1. Restriction to sight distance at horizontal curves either due to obstruction inside curve such as building, trees, etc. or due to inability of head light to through the beam along the curve path.
2. Restriction to sight distance at vertical summit curves on the other side if the curve is not carefully selected.
3. Restriction to sight distance at vertical valley curves on the other side if the curve is not carefully selected.
4. At intersections the sight distance is reduced if an obstacle either in the form of building or greeneries comes up.

**Types of Sight Distance**

1. Stopping sight distance
2. Over taking sight distance

- **Stopping sight distance**

  Stopping sight distance is defined as the minimum sight distance required along the road for the driver to stop the vehicle at designed speed safely without colliding with the other vehicle. The stopping sight distance is not constant, but

it varies depending upon the situation.

**Factors Affecting Stopping Sight Distance**

1. **Total reaction time:** It is the time taken from the instant the object is visible by the driver to the instant the break is applied by the drivers' feet. In average total reaction time is taken as 2.5 sec.

1. Speed of vehicle
2. Breaking efficiency
3. Coefficient of friction
4. Slope of road surface

**Expression for Stopping Distance**

Stopping distance is the sum of lagging distance and breaking distance.

Lagging distance: Distance travelled by vehicle during total reaction time. It is also known as reaction distance.

Lagging distance = 0.278 vt meters

Breaking distance: The distance travelled by the vehicle after the application of breaks to the instant the vehicle come to dead stop is known as breaking distance. Breaking distance = $v^2 / 2gf$ We know that,

SD = Lagging distance + Breaking distance

SD = $0.278 Vt + V^2 / 2gf$

In case of slopping road with n% gradient above expression reduces to, SD= $Vt+( v^2 /2gf(f\pm0.01n)$

Where, v = Designed speed of vehicle in m/s t= total reaction time in second f= coefficient of friction n = gradient of road in %

Note: Here +ve and -ve sign with n is applicable for ascending and descending gradient respectively.

**Relationship between Stopping Distance and Stopping Sight Distance**

Case I: SSD = SD for one-way traffic with single lane

Case II: SSD = SD for tow way traffic with multi-lane

Case III: SSD = 2 SD for tow way traffic with single lane

- **Overtaking Sight Distance**

  It is the distance open to the vision of drivers in the vehicles intending to overtake the slow-moving vehicle ahead with safety against the vehicle coming from opposite direction. This distance is also called passing sight distance.

1. Factors affecting overtaking sight distance
2. Speed of overtaking vehicle, overtaken vehicle, and vehicle coming from opposite direction.
3. Distance between overtaking and overtaken vehicle
4. Skill and reaction time of driver

## Exercise

### Choose the correct answer from the given alternatives.

1. The most raised portion of the pavement is called _____
   a. Super elevation
   b. Camber
   c. Crown
   d. Kerb

2. The main purpose of providing camber is _____
   a. To collect surface water
   b. To maintain equilibrium
   c. To follow IRC specifications
   d. To follow geometric specifications

3. The length visible to driver at any instance of time is called _____
   a. Sight distance
   b. Visibility limit
   c. Head light distance
   d. Overtaking sight distance

4. The most important factor that is required for road geometrics is _____
   a. SSD
   b. OSD
   c. ISD
   d. Speed of vehicle

5. A part of pavement raised with respect to one side keeping the other side constant is called _____
   a) Footpath
   b) Kerb
   c) Super elevation
   d) Camber

### Write short answer to the following questions.

1. Define superelevation. Where and why, is is provided?
2. Why is extra widening needed at horizontal curves?
3. What is sight distance? Write an expression to calculate the stopping distance of a vehicle.
4. What is the function of a median strip.
5. Define traffic lane and Carriageway.
6. What is the function of Kerb?
7. Explain formation width with sketch.

## Write long answer to the following questions.

1. Draw a cross section of road in embankment showing various components.
2. What are the reasons for providing extra widening on horizontal curves?
3. Define shoulder. What are its advantages?
4. Define camber. What are the objects of camber?
5. Explain right of way. What is the purpose of right of way?
6. What is stopping sight distance? What are the factors on which the stopping sight distance depends?
7. Explain sight distance and factors causing its restriction.

# Unit 4 : Highway Materials

## 4.1 Importance of Soil Engineering in Road Construction

The soil is the most important yet most neglected in a road construction project. All structures, buildings, roads, bridges, dams and even life itself is based on the soil. The soil is the natural foundation that supports all highway structures and investment. Most clients see soil investigation as a waste of funds despite being the cheapest in the construction process, hardly is the cost of soil test up to one percent of the cost of construction. Some contractors to ignore the importance of proper soil investigation and analysis and base their design on assumed bearing capacity and rate of settlement.

Soil investigation helps to determine varying physical and Engineering properties of soil, which can vary from place to place and from layer to layer even within the limits of the proposed structure. Soil characteristics can change considerably within a small area. Weather, climatic changes, and site management can in the future affect the bearing qualities of the soil, if the foundation is not designed properly to the bearing capacity of the soil, then they will fail and so will the highway and its components. This is as important as the entire project itself that may cause long term complications and may result to loss of life and property, endanger residents and users, tenants and damage other neighboring properties.

Importance of soil engineering in road construction: Soil is the cheapest and the most widely used material in any highway system. Also, all road pavement structures eventually rest on soil foundation, which supports load of pavements plus vehicular loads coming over it. Thus, through study of engineering properties of soil is of vital in design of pavement structure.

**The Main Points are Discussed Below**

- All road structures like bridges culverts, etc. rest in soil and hence study of soil engineering is important for foundation design of such structure
- Retaining walls are frequently used in road construction. Soil engineering suggests design procedure of such retaining walls. Soil engineering helps to

decide the safe side slope required for road embankments

- Drainage requirements of subgrade is decided by study of permeability of soil in soil engineering
- Soil engineering suggest value of bearing capacity for different soil, which is needed for pavement design
- Soil engineering suggest various method to improve the strength of subgrade soil
- Soil stabilization technique is described in soil engineering
- Problems of landslide and measure adopted to combat them are studied in soil mechanics, which is useful in hill road construction.

Hence, The soil investigation helps to determine the following: bearing capacity of the soil which determine the load sustenance capability of the soil, rate of settlement of the soil which affect the rate at which any loaded vehicles placed on it settles, to select a type and depth of foundation, to select suitable construction technique , to predict and resolve probable foundation problems, to determine if the land can be subjected to subsidence and cause sinking of the subgrade soil, to determine water table and drain off which affects humidity within the subgrade soil and greatly affects the character of a soil which varies considerably with water content, mineral or chemical component of the soil that might affect the choice of construction materials.

## 4.2 Grading for Road Construction

Grading in civil engineering and landscape architectural construction is the work of ensuring a level base, or one with a specified slope. The final elements of site development are road construction and grading. Completion of these last efforts gets the project ready for final use, whether it be for homes, commercial building construction, or public roadway. Road construction begins with grading of sub-base after all underground work is completed and is followed by curb installation. After appropriate curing of the concrete curbs the road base is installed and after the base cures the asphalt wearing surface is installed. Graders are used to conform the uniformity and to maintain the grades.

Final site grading is done along with the road building effort and is finalized just before the asphalt goes down. Final grading is the last step in the earthwork process. It results in areas being made ready for vertical construction of homes or commercial buildings.

## 4.3 Subgrade Soil, its Importance and Requirements for Practical Use

**Subgrade Soil**

Soil is the deposition of the mineral matters formed by disintegrations of rocks, by the action of water, frost, temperature, pressure or by plant or animal life.

The subgrade soil is the integral part of road pavement structure as it provides the support to the pavement from beneath. The main function of the subgrade is to give adequate support to the pavement and for this subgrade, soil should possess sufficient stability under adverse climate and loading condition.

The formations of waves, corrugations, and rutting, in black top pavement and phenomena of pumping, blowing and consequent cracking of cement concrete pavements are generally due to poor subgrade-soil conditions.

**Importance of Subgrade Soil:** integral part acts as main foundation gives support to the pavement bears the overall traffic and pavement load thus acts as principal highway material

**Requirements of Sub-grade Soil for Practical Use**

Following properties are the required for the practical application as subgrade soil acts as the foundation in highway engineering:

**1. Stability**

The subgrade soil should be stable and strong to resist permanent deformation under loads, resistance to weathering and it should have ability to provide adequate support to the pavement.

**2. Incompressibility**

Soil used in the subgrade and embankment construction should be incompressible to avoid differential settlement of the pavement after its constriction.

**3. Permanency of Strength**

Permanency of strength is the property of soil, which allows the subgrade to support pavement with same degree of strength under the varying condition of moisture and weather for long time.

**4. Ease of Compaction**

The strength of subgrade soil depends upon its dry density. Higher the dry density,

greater the strength of soil. The ease of compaction is the property of soil which, ensure the higher dry density with minimum compaction effort. Thus, if soil is easy to compact, we can able to increase its strength easily in minimum effort.

**5. Good Drainage**

Increase in moisture content of sol decreases its strength. Presence of moisture in subgrade soil, due to poor drainage characteristic reduces the strength of subgrade soil. Thus, the soil having good drainage characteristic is essential to avoid excessive moisture and frost action.

**6. Minimum Change in Volume and Stability Under Adverse Condition of Weather and Ground Water**

It is required to ensure minimum variation in its expansion.

## 4.4 Stone Aggregates, Types and Requirements

**Stone Aggregates**: Aggregates are granular mineral material (such as sand, gravel, crushed stone) used with a bonding medium (such as cement or clay or bitumen) to make concrete, plaster, or terrazzo. Stone aggregates form the major portion of pavement structure, and they are the prime material used in the construction of different pavement layers. The aggregate used in the various pavement layers must sustain different magnitude of load. The aggregate of the pavement surface has to resist,

1. The wear due to abrasive action of traffic
2. Deterioration due to weathering
3. Highest magnitude of wheel load stress

Stone aggregate is a collective term for the mineral materials such as sand, gravel, and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials such as bituminous concrete and Portland cement concrete. By volume, aggregate generally accounts for 92 to 96 percent of Bituminous concrete and about 70 to 80 percent of Portland cement concrete. Stone aggregates are used in the construction of various pavement layers such as

I) Bituminous pavement layer of flexible pavement

II) Cement concrete mixes used for rigid pavement

III) Granular base course

IV) Granular sub-base course. Thus, stone aggregates form one of the important components of highway materials

Road aggregate may be used in road pavement in single size or mixing by gradation of different size to increase density and hence strength.

**Types of Aggregate**

- **Based on Source of Origin**

i. Natural aggregates ii. Crushed aggregates

- **Based on Size**

i. Coarse aggregates

ii. Fine aggregates

- **Based on Types of Rock**

i. Aggregate obtained from igneous rock

ii. Aggregate obtained from sedimentary rock

Aggregate obtained from metamorphic rock

- **Based on Strength**

i. Hard aggregates

ii. Soft aggregates

- **Based on Shape**

I. Rounded aggregates

II. Irregular aggregates

III. Flaky aggregates: Least dimension is less than 3/5 of its mean dimension

IV. Angular aggregates.

V. Elongated aggregates: Greatest dimension is greater than the 9/5 times their mean dimension

**Requirements of Stone Aggregates**

**1. Strength**

The ability of a material to withstand various forces is called strength. The aggregates used in top layers are subjected to (i) Stress due to traffic wheel load, (ii) Wear and

tear, (iii) crushing. For a high-quality pavement, the aggregates should possess high resistance to crushing, and to withstand the stresses due to traffic wheel load.

**2. Hardness**

Resistance to abrasion is known as hardness. The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. They should be hard enough to resist the wear due to abrasive action caused by the movements of traffic. Abrasive action may be increased due to presence of abrasive material like sand between the tyres of moving vehicle and aggregates exposed at the top surface.

**3. Toughness**

Resistance of the aggregates to impact is termed as toughness.

Due to irregularities in the road surface impact action is developed. The constant impact of heavy traffic loads tends to break the stone aggregates into small pieces. The aggregate used in the road construction should be tough enough to resist fracture under such impact

**4. Shape of Aggregates**

Aggregate particles may have rounded cubical, angular, flaky or elongated shapes. It is evident that the flaky and elongated particles will have less strength and durability when compared with cubical, angular or rounded particles of the same stone. Hence too flaky and too much elongated aggregates should be avoided as far as possible. Aggregates having angular particles should be preferred

**5. Adhesion with Bitumen**

The aggregates used in bituminous pavements should have less affinity with water when compared with bituminous materials; otherwise, the bituminous coating on the aggregate will be stripped off in presence of water.

**6. Durability**

The property of aggregates to withstand adverse action of weather is called soundness. The aggregates are subjected to the physical and chemical action of rain and bottom water, impurities there-in and that of atmosphere, hence it is desirable that the road aggregates used in the construction should be sound enough to withstand the weathering action.

**7. Freedom from Deleterious Particles**

Aggregates used in bituminous mixes usually require the aggregates to be clean, tough and durable in nature and free from excess amount of flat or elongated pieces, dust, clay balls and other objectionable material. Similarly aggregates used in Portland cement concrete mixes must be clean and free from deleterious substances such as clay lumps, silt and other organic impurities.

**8. Cementation**

Mixing and making unite property of stone aggregate with other material should be good.

## 4.5 Binding Materials, Its uses and Requirements

**1. Binding Materials**

The materials used to unite or bind two or more materials during the construction of pavement is known as binding material. These materials are divided into following categories.

a. **Stone Dust:** It produces semi rigid or semi flexible bonding between the mineral Materials

b. **Inorganic Materials:** It produces rigid bond between the mineral materials.

Example: cement, lime, etc.

c. **Organic Materials:** it produces thin film or layer, which is flexible or reversible in Nature

Example: bitumen

**2. Other Materials**

The other materials used in highway construction are concrete, reinforcing steel, timber, stone, brick boulders, cobbles, etc.

**Bitumen**

Bitumen is a liquid or solid material black or dark brown in color. It has adhesive properties consisting essentially of hydrocarbons (compound of carbon and hydrogen) which is soluble in carbon disulphide. It is non crystalline solid or viscous material derived from petroleum. Bitumen is main binders used in road construction which is obtained from petroleum.

Bitumen is manufactured by fractional distillation of crude petroleum product.

- Bitumen softens gradually when heated.

- Possesses waterproofing and adhesive properties.
- Bitumen is classified into two categories as per the source of origin. The first is Petroleum bitumen and second is natural bitumen. Soluble in carbon disulphide, carbon tetra chloride, chloroform, benzene etc.

**Petroleum Bitumen**

It is the product of processing crude petroleum and its resinous residue.

**Natural Bitumen**

Bitumen is also found as a natural deposit; in which case it is known as native bitumen or natural bitumen.

**Bye Product of Bitumen**

1. **Cut Back:** It is solution of bitumen in volatile or partly volatile solvent such as Kerosene, creosote. Addition of solvents lowers the viscosity of bitumen.
2. **Emulsion:** Finely divided bitumen held in suspension in an aqueous medium is called bitumen emulsion. It is used in soil stabilization.
3. **Asphalt:** A mixture of bitumen and inert mineral matters. Which may occur in natural deposit or produced by artificial means. Bitumen is binding medium in asphalt

**Desirable Properties of Bitumen**

1. The viscosity of bitumen at the time of mixing with aggregates should be adequate. This is achieved either by
   a. Heating the bitumen and aggregate prior to mixing
   b. By using in the form of cut-back
   c. By using in the form of emulsion of suitable grade
2. The bituminous binder should become sufficiently viscous on cooling so that compacted bituminous pavement layer can gain stability and resist deformation under traffic loads.
3. The bituminous binders used should not be highly temperature susceptible. During the hottest weather, bituminous surface should not become too soft or unstable. During cold weather the mix should not become too hard and brittle, causing cracking of surface.
4. The bitumen binder should have sufficient adhesion with aggregates in the mix in Presence of water.

5. There has to be adequate affinity and adhesion between the bitumen and aggregate used in the mix. The coated binder should not strip -off from the stone aggregate under stagnant water.
6. It is desirable that bitumen binder used in bituminous mixes form ductile thin film around the aggregates to serve as satisfactory binder in improving the physical interlocking of the aggregates.

## Exercise

### Choose the correct answer from the given alternatives.

1. The layer which is constructed above embankment is called _____
   a. Sub grade
   b. Fill
   c. Base
   d. Sub base

2. Bitumen is a by-product of _____
   a. Wood
   b. Petroleum
   c. Kerosene
   d. Coal

3. Tar is a by-product of _____
   a. Wood
   b. Petroleum
   c. Kerosene
   d. Coal

### Write short answer to the following questions.

1. What are the different types of binding materials used in road construction?
2. What are the bye-product of bitumen? Discuss in short
3. Discuss the importance of soil engineering in road construction.
4. Mention the properties of bitumen

### Write long answer to the following questions.

1. What is the importance of studying behavior of soil as a highway material?
2. What are the desirable properties of subgrade soil?
3. What are the desirable properties of aggregates used in pavement construction?
4. Discuss the desirable properties of paving bitumen

# Unit 5 : Highway Drainage

## 5.1 Drainage System and Its Importance

Highway drainage may be defined as the process of interception and removal of water from over, under and vicinity of the road surface. There are two types of highway drainage system, they are: (1) surface drainage system (2) Sub-surface drainage system

**1. Surface Drainage System**

Removal and diversion of surface water from highway and adjoining land is known as surface drainage. Surface drainage of roadway is achieved with the help of well designed and constructed surface drainage system consisting of following components such as,

I. Camber or Cross slope of pavement surface and shoulder

II. Roadside drains

III. Cross drainage structures such as culverts bridge

In surface drainage system, the water from the pavement surface and shoulder is first drained off to the roadside drain with the help of camber or cross slope. The collected water in the roadside drain is then disposed of to the natural drain with the help of cross drainage structure.

**2. Sub-surface Drainage System**

Removal and Diversion of excess subsoil water from the subgrade is known as sub-surface drainage system (The removal of water located below the ground level is known as sub surface drainage) system. The subsurface drainage systems,

Enables intercepting the seepage flow of water and diverting same away from roadway to nearest water course

Help in lowering the ground water level well below the subgrade Helps in controlling the capillary rise of water

**Importance of Highway Drainage**

1. Road surface if made of soil, gravel or water bound macadam becomes soft and loose strength.

2. The road subgrade may be softened and its bearing capacity reduced
3. Variation in moisture content in expensive soils causes variation of volume of subgrade and thus failure of road
4. Failure of formation slopes is also attributed to poor drainage
5. If rainwater is not properly drained and allowed to flow along the road side for long distances, slips and landslides may occur causing road failures
6. Erosion of side slopes, side drains, and formation of gullies may result if proper drainage conditions are not maintained
7. Flexible pavement s failure by formation of waves and corrugations is due to poor drainage
8. Continuous contact of water with bituminous pavements causes failure due to stripping of bitumen from aggregate
9. Rigid pavement s prime cause of failure in by mud pumping which
10. Excess moisture causes increase in weight and thus increase in stresses and simultaneous reduction in strength of soil mass. This is main reason of failure of earth slopes and embankment foundation.

## 5.2 Requirements of Good Highway Drainage System

1. The surface water from the carriage way and shoulder should be effectively drained off without allowing it to percolate to subgrade.
2. The surface water from adjoining land should be prevented from entering the roadway.
3. The side drain should have sufficient capacity and longitudinal slope to carry away all the surface water collected.
4. Flow of surface water across the raid and shoulders and along the slopes should not causes formation of cross ruts and erosion.
5. Seepage and other source of underground water should be drained off by sub- surface drainage system.
6. Highest level of water table should be kept well below the level of sub-grade, preferably by at least 1.2m.
7. In water-logged areas special precautions should be taken.

**Surface Drainage System**

Removal of rainwater (surface water) from road surface and roadside ground is called surface drainage. The water is first collected in longitudinal drains and then the water is disposed of at the nearest stream or water course. Surface drainage consists of two operations.

I. Collection of surface water, and

II. Disposal of the collected surface water

Surface drainage system may be divided into three categories.

a. Drainage system in rural highway

b. Drainage system in urban road

c. Drainage system in hill road

**Drainage System in Rural Highway**

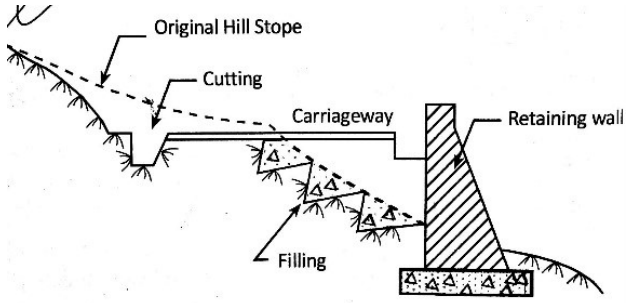
In rural highway, the water from the pavement and shoulders is first drained off to the roadside drains with the help of cross slope or camber. These side drains of rural roads are open drains of trapezoidal shape, cut to suitable cross section and longitudinal slope. In case of roads in cutting, drains are provided along both sides of the road, just adjacent to the shoulder. In case where space is restricted in cutting, open drains are dangerous to be provided and hence covered drains or drainage trenches properly filled with layer of coarse sand and gravel may be constructed.

**Drainage System in Urban Road**

In urban roads because of the limitation of land width and also due to presence of footpath, dividing island and other road facilities, it is necessary to provide underground longitudinal drains. Water drained from the pavement surface can be carried forward in the longitudinal direction between the kerb and the pavement for the short distance. This water may be collected in catch pits at some suitable intervals and lead to underground drainage pipes.

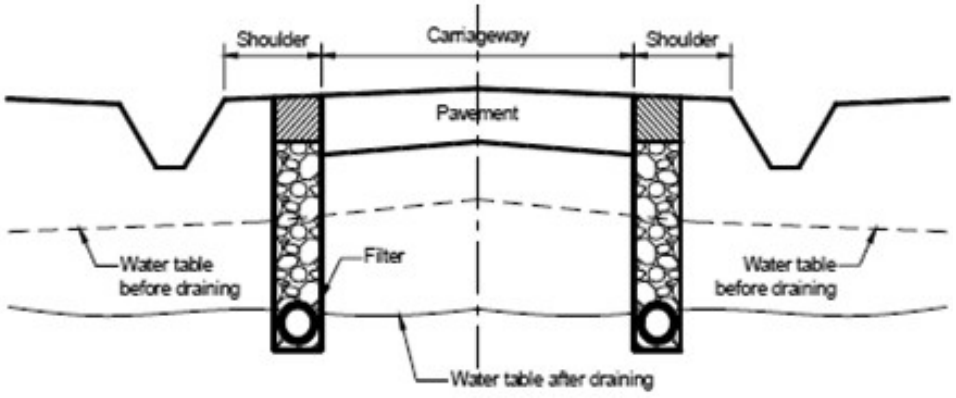
**Drainage System in Hill Road**

In hill road, drainage problems are more complex. Apart from the drainage from road formation, water following down the hill also has to be efficiently intercepted and disposed of downhill side by constructing suitable cross drainage work in the form of culverts and bridges. If hills roads are not properly drained, slips and rocks slides may take place and block the road during monsoon.




**Sub-Surface Drainage System**

Stability and strength of road surface depends upon the strength of subgrade. Subgrade is the foundation layer of the road whose strength largely depends upon its moisture content. With increase in moisture content strength of subgrade decreases. Following are the cause of moisture variation in subgrade.




**Cause of Moisture Variation in Subgrade**

**1. By Free Water**

i. Seepage of water from higher ground adjacent to the road

ii. Penetration of water through the pavement

iii. Transfer of moisture from shoulder and pavement edge

**2. By Ground Water**

i. Rise and fall of water table

ii. Capillary rise from lower soil layer

iii. Transfer of water vapors through soil In case of sub surface drainage of roads, every effort should be made to reduce the change or variation in moisture content to a minimum. In sub surface drainage system of highway following methods are used to control sub soil water.

**Control of Sub-Soil Water (Methods of sub-surface drainage)**

**1. By Lowering Water Table**

**2. By Control of Seepage**

**3. By Control of Capillary Rise**

**1. By Lowering Water Table**

If underground water table is more than 1.5m below the subgrade of road, it doesn't t require any method for lowering water table. But if it is closer than this value the best remedy is to take the road formation on embankment of height not less than 1.2 to 1.5m above the ground level. When the formation is to be kept at or below the general ground level at cutting, it is necessary to lower the water table

If soil is relatively permeable, it may be possible to lower the water table by construction of longitudinal drainage trenches with drainpipe and filter sand as shown in figure.

If soil is relatively less permeable, lowering of water level may not be adequate under the Centre of pavement. Hence, in addition to longitudinal drainage trenches transverse drains must be constructed at suitable intervals as shown in figure.

**2. Control of Seepage Flow**

When surface of ground and impervious layer embedded below it are sloping towards the road, the seepage flow is likely to reach the road subgrade and affect its strength. If seepage zone is at depth less than 0.6 to 0.9 m from the subgrade level, it should be intercepted to keep seepage line at safe depth below the road subgrade. Seepage flow can be intercepted by constructing longitudinal drainage trenches with drainpipe and filter sand as shown in

figure.

**3. Control of Capillary Rise**

If the capillary rising water is very nearer to the subgrade of road and likely to affect the strength, steps should be taken to arrest the capillary rise of water. Following method can be used to control capillary rise of water.

## 5.3 Field Construction Procedure of the Drainage System

**It includes**

i. Marking of alignment.

ii. Excavation.

iii. Next step is laying of concrete base on the binded surface and positioned reinforcement.

iv. After setting a drying of the concrete base, next is to position the side wall panel form work.

v. Backfilling and compaction of the backfilling is done immediately after the back filling to avoid settlement.

## Exercise

### Choose the correct answer from the given alternatives.

1. The highway drainage requirement don't include _____

   a. Effective drainage
   b. Water entering the roadway
   c. Sufficient longitudinal slope
   d. Erosion free

2. The excess water on shoulder in a dry region with a good drainage system cause _____

   a. Water stagnation
   b. Floods
   c. Damage to pavement
   d. Increase of initial cost

3. How many components are present in the surface drainage system?

   a. One
   b. Two
   c. Three
   d. Four

### Write short answer to the following questions.

1. Write the importance of a drainage system?
2. Write the requirements of a good drainage system?
3. Write the field construction procedure of a highway drainage system?
4. Write the types of drainage system?

### Write long answer to the following questions.

1. Explain the different types of drainage system.

# Unit 6 : Road Pavement and Road Making Machinery with Its Uses

**Road Pavement**

Road pavement can be defined as a relatively stable layer constructed over the natural soil for the purpose of supporting and distributing the wheel load and providing an adequate surface for the movement of vehicles with certain speed safely, comfortably and economically.

The main function of the pavement is to support and distribute wheel load of vehicles over a wide area of the underlying sub grade soil.

**Pavement Layers**

Pavement consists of one or more layers of sub grade, subbase, base and surface or wearing course.

- Surface course is the top course and is provided to provide a smooth, dust free, reasonably waterproof and strong layer
- Base course is the medium through which the stresses imposed are distributed evenly to the underlying layer
- Subbase layer provides additional help in distributing the loads
- Sub-grade course is the compacted natural earth

## 6.1 Types of Pavements

Based on the structured behavior, road pavements are generally classified into two categories.

**i. Flexible Pavement**

**ii. Rigid Pavement**

**i. Flexible Pavement**

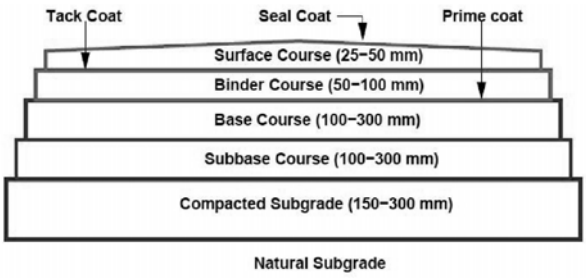
The pavement which has very low flexural strength and are flexible in their structural behavior under the load are called flexible pavement.

The flexible pavement layers reflect the deformation of the lower layers on to the surface of the layer. Thus, if lower layer somehow gets deformed, the surface of pavements also get deformed. Different pavement layers used in

flexible pavement are soil sub grade, subbase layer, base layer and surface layer.

The flexible pavement layers transmit the vertical loads to the lower layers by grain-to-grain transfer through their point of contact in the granular structure.

The load spreading capacity of the flexible layer depends on the type of material and mix design factor. The materials which fall in the category of flexible pavement layers are soil aggregate, mix, crushed aggregate, granular materials with bituminous kinder, bituminous concrete. The basic design principle of flexible pavement is based on layered system with better materials on the top where the intensity of stress is high and inferior materials at the bottom where the intensity of stress is low.




Typical cross section of a flexible pavement

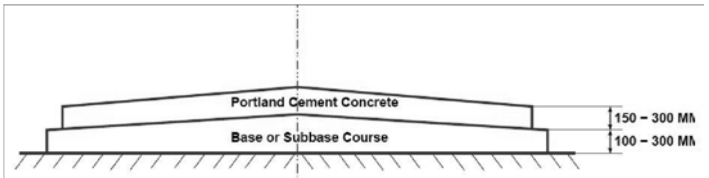
**ii. Rigid Pavement**

Rigid pavements are those which possess considerable flexural strength. The rigid pavements are made of cement concrete which may be either plain, reinforced or prestressed.

The rigid pavements have a slab action and can transmit the wheel load stresses through a wider area below.

The main difference between rigid and flexible pavement in their structural behavior is that the critical condition of stress in rigid pavement is the maximum flexural strength occurring in the slab due to wheel load and temperature changes whereas in flexible pavement it is the distribution of compressive stress to the lower layers and lastly over the soil sub grade.

Usually, the rigid pavement structure consists of a cement concrete slab, below which a granular base or subbase course may be provided. A good base or subbase course under the cement concrete slab increases the overall pavement life.




Typical Cross section of Rigid pavement

**Differences Between Flexible and Rigid Pavement**

| Flexible pavement | Rigid pavement |
|---|---|
| Flexible pavement under heavy loads yield to excessive stresses resulting in local depression of the surface | Rigid pavement under heavy loads ruptures |
| The flexible pavement has self-healing properties | The rigid pavement does not have self-healing properties |
| The pavement which has very low flexural strength and are flexible in their structural behavior under the load are called flexible pavement | Rigid pavements are those which possess considerable flexural strength |
| Strength of flexible layer is a result of building up thick layer and thereby distributing the load over sub grade | Strength of rigid layer is by bending action |

## 6.2 General Structure of Pavement Sub-grade, Sub-base, Base, and Surface Coarse Uses

### 1. Sub Grade

The soil sub grade is a layer of natural soil prepared to receive the layer of pavement materials placed over it. The sub grade is the lowest layer of pavement layer system which ultimately supports all other pavement component layers and the traffic loads. The top layer of the sub grade soil should be well compacted, under controlled condition of optimum moisture content to achieve maximum dry density.

### 2. Subbase Layer

Subbase layers are made of broken stones bounded or unbounded. Subbase layer may sometimes be constructed by stabilized soil or selected granular

soil. The subbase course must serve as an effective drainage layer of the pavement and has to sustain lower magnitude of compressive stress than base course.

**3. Base Layer**

The base course is considered as the most important component of flexible pavement layer which sustains the wheel load stresses and disperses through larger area on to subbase layer below.

Base course layer protects the sub grade against the frost action. At subbase course it is desirable to use smaller size graded aggregate or soil aggregate mixes or soft aggregate instead of large boulder stone.

**4. Wearing Course or Surface Course**

In flexible pavement, wearing surface is generally made of bituminous material whereas in rigid pavement; the cement concrete slab is used as wearing course.

**Surface Courses Perform the Following Functions**

Provides watertight layer against filtration of surface water. Provides hard surface which can understand the pressure exerted by tyre of vehicles.

Provides smooth and dense riding surface.

## 6.3 Role of Labor vs Machinery in Road Construction

Construction industry uses different types of equipment for different purposes. Equipment relating to earthwork, transportation, aggregates production and handling, concrete production, equipment for road pavement, tunnel construction etc. are the typical example for such industry.

**Advantages of Using Equipment (Machinery)**

1. Large and complex work can be carried out easily
2. Faster rate of work progress can be achieved
3. Higher quality of work can be achieved
4. Machinery can work in adverse weather, climate condition and topography
5. Equipment is free from social and emotional factors

**Disadvantages of Using Equipment (Machinery)**

1. Required huge capital investment

2. Unavailability of trained and skilled operator
3. Need costly repair
4. Replaces large number of labor and arise unemployment
5. Less environmentally friendly than green technology

## 6.4 Earthwork Machinery, Types and Uses

### 1. Excavators

Excavators are large earth moving equipment that can be available over wheels or tracks. Excavators are commonly used for digging rocks and soil, but with its many attachments, it can also be used for cutting steel, breaking concrete, drilling holes in earth, crushing rocks, and moving earth. The most common uses of an excavator are:

- Material handling
- Digging of trenches, holes and foundations Brush cutting with hydraulic attachments.
- Lifting

### 2. Backhoe

Backhoe loaders are very similar to tractors with a slight difference that they contain an adjustable, shovel in front of the equipment and a small bucket in the back of the loader, used for digging. It is used to excavate below the natural surface on which it rests. They can move dirt, backfill, dig trenches and place smaller pipes into place.

### 3. Front Shovel

A front shovel (also stripping shovel or power shovel) is a bucket equipped machine, usually electrically powered, used for digging and loading earth or fragmented rocks.

- They are mounted on crawler tracks or wheel.
- To excavate the earth and to load the trucks
- It is used to excavate earth of all classes except hard rock and load it into wagons.

### 4. Clam Shell

Clam shell consists of a hydraulically controlled bucket suspended from a

lifting arm. It is mainly used for deep confined cutting in pits and trenches.

It is having bucket of two halves which are hinged together at top. It is used to excavate soft to medium materials and loose materials.

**5. Bulldozers**

Bulldozers are considered one of the strongest and toughest heavy equipment used in the construction industry. Bulldozer is a tractor equipped with a front pusher blade, which can be raised and lowered by hydraulic rams. They are normally used to push piles of earth. Bulldozers have a wide variety of roles including excavating soils and weak rocks, moving excavated material over short distances, spreading materials, and trimming earthworks.

**6. Trenchers**

A trencher is heavy equipment used to dig trenches on which pipes can be laid down.

**8. Scraper**

Scraper is another type of construction equipment, which is used to scrap a thin layer of soil, and then carry it meters away as desired. They are commonly used in big project sites.

**9. Motor Graders**

Graders are used to spread fill and finely trim the subgrade. They have a long blade that can be adjusted to meet certain angles to create a flat surface. The blade is used to trim and redistribute soil and therefore graders usually operate in the forward direction.

**10. Dump Trucks**

They are used to move excavated soil from one place to other. They have ability to unload the soil mechanically by tilting of its bucket with powerful hydraulic system.

**11. Drag Line**

They are used to excavate soft earth from below ground and to deposit or to load in wagons. Output of dragline is measured in Cubic Meters per hour.

They are used for bulk excavation below its track level in loose soils, marshy land and areas containing water.

## 6.5 Compaction Equipment

Earth compaction is done to remove the air entrapped in the soil and making it denser to acquire required strength. The equipment uses to remove the air from the soil is called compacting equipment. Hence, the compacting equipment's may also be classified as rollers, rammer and vibrators.

**Roller:** The principle of roller is the application of pressure, which is slowly increased and decreased. The various types of rollers which are used for compaction are:

1. Three-wheel road roller
2. Sheep foot rollers
3. Pneumatic tyre rollers
4. Vibratory roller

### 1. Pneumatic Tyre Rollers

1. In this type of rollers, number of pneumatic wheels (9~~11) are mounted on two or more axle under a loading platform
2. These are surface rollers and work on the principle of kneading action to produce compaction in the soil below.
3. This type of roller has rubber tyres, generally it consists of 3 in the front and 4 in the rear.
4. They are non-vibrating types. Sand bags or some other weights can be placed over the platform to provide the effective compaction. Pneumatic tyres are so spaced that a complete coverage in obtained with each pass of the rollers.
5. They are most effective for compacting both cohesive soil and cohesion less soils especially not plastic silts and fine sands.
6. The weight of such roller may be as large as 50 ton and 2-4 passes are generally sufficient to achieve compaction of 60 cm thick soil layer.
7. Light roller → weight up to 20 tons and thickness up to 15cm.

*Figure: Pneumatic Tyre Roller*

**2. Sheep Foot Rollers**

*Figure: Sheep Foot Rollers*

1. Sheep foot rollers consist of hollow steel cylinder with projecting feet.
2. The weight of the roller can be increased by filling water or wet soil in the drum.
3. The weight, diameter and width of the roller may be varied and the shape and size of the feet.
4. The efficiency of the sheep foot roller depends on the weight of the roller and the number of feet in contact with the ground at a time. They are most suitable to compact clayey soil. The thickness of compacting layer is kept about 5cm. About 24 or more number of passes of the roller may be necessary to obtain adequate compaction.
5. The top layer of the sub grade or fill may be compacted using smooth wheel roller to get a properly finished surface.

**3. Vibratory Roller**

1. Vibratory rollers are most suitable for compacting dry cohesion less granular

material.

2. Vibrator mounted roller is called vibratory roller to give combined effect of rolling and vibration.
3. They are commonly used in compacting a wide range of materials.


**4. Three Wheeled Road Roller or macadam Rollers**

1. The three wheeled roller is also known as macadam rollers with gross weight of 4-18 ton
2. The compacting efficiency of three wheeled roller depends on the weight, width and diameter of each roller.
3. They are useful for finishing operation after compaction of fills and for compacting granular base course of highway.
4. They are suitable for compacting gravel, sand, crushed rock and any material where crushing action is required.
5. The compaction of any roller depends upon the following factors: a. Contact Pressure
   b. Number of passes
   c. Layer of thickness
   d. Speed of roller
   e. Weight of roller

## 6.6 Transporting Equipment

In compaction site the earth moving work is especially carried by transportation equipment. Large scale cutting and embankment is necessary in construction. Therefore, transportation equipment is equally important in moving the earth and to carry gravel and other material from borrow pit.

The following are the transportation equipment's:

**1. Trucks or Tippers**

Trucks are the hauling units that provide transportation facility for excavated materials, aggregates, construction equipment from one place to another. Trucks can be an ordinary or dump type. Ordinary trucks are also called flat-bed trucks which are not capable of self-empty the material but dump trucks are capable of dumping the load automatically by lifting the body with the help of hydraulic attachment. Trucks provide relatively low hauling cost due to their higher travel speed.

**2. Rail Wagons**

Mostly rail wagon is used in tunnel excavation. They are used when large quantity of material has to be transported to large hauling distance.

**3. Mini Dumpers**

Mini dumpers are small front end dump trucks with small capacity bowl in the front. They can dump or unload automatically, hence very handy to use in construction sites. They are used when material to be transported is very small quantity to a relatively short distance.

**4. Belt Conveyor**

Belt Conveyor is generally of fixed type. Belt Conveyor are loaded the help of loaders. It is used in gravel and sand.

**5. Bucket Conveyor**

They are commonly used to transport earth in vertical direction. Bucket conveyors are efficient means of transporting loose materials vertically. Loading is done manually and emptying is done automatically.

## 6.7 Watering Equipment

**1. Water Pump and Dewatering Equipment**

**2. Water Tanker with Sprinkler**

**1. Water Pump and Dewatering Equipment**

Pumps and dewatering equipment are used to remove water from a volume of liquid, solid material or soil. Pumps simply remove liquid whereas dewatering equipment separates water from another material such as soil.

**2. Water Tanker with Sprinkler**

A water tanker with sprinkler is a vehicle equipped to transport and distribute water through a spraying system. It is commonly used for dust suppression on roads, irrigation in agriculture, and cleaning public spaces. The sprinkler mechanism ensures even water distribution, making it efficient for environmental and construction site applications.

## 6.8 Rock Excavation Machinery

Following are the commonly used rock excavating equipment in the construction works.

1. **Excavator:** Excavator has a small hoe in its back. Hoe is teeth attached bucked. It is capable of excavating to a depth. Excavation is done by teeth attached to a bucket, which is also capable of loading the excavated materials directly to the transporting vehicle by changing the bucket it can be converted to driller, power shovel, etc. Excavators are classified on the digging motion. An upward motion unit is known as shovel and downward motion is Hoe.

2. **Dozers/Bulldozers:** A dozer is a versatile mechanical instrument for scraping and the excavating in both firm and hard soil. It can work in the worst conditions of site like waterlogged as well as loose soil where other equipment cannot run. It can push the excavated material to the other place with its blade.

   **Jobs of Bulldozer**

   - Remove vegetation
   - Remove topsoil
   - Shallow excavation
   - Leveling ground and spread soil

3. **Power Jack Hammer:** Power jack hammer are the equipment used to drill holes in the hard rock and are used to excavate hard rock by drilling and blasting method. These types of jack hammer are very useful for the opening

track in mountainous road when larger equipment like air compressor cannot be taken to site.

4. **Pneumatic Rock Drills:** Pneumatic rock drills are the rock drilling operated by compressed air and hence they are called pneumatic rock drills. They can bore a hole in the hard soil up to the 5m in hard rock.
5. **Air Compressor:** These are very important part of excavating equipment s when excavation to hard rock. These compressors drive the drilling machines to drill holes in the rock. Compressor used in the construction project is relatively small, simple and strong enough so that they need minimum maintenance. Some other uses of compressor are:
    a. Drill hole in rock for blasting and cleaning
    b. Cutting materials with the help of pneumatic circulars saws

## 6.9 Production of Aggregates

1. Aggregates must be produced at site. If the quantity needed is very large.
2. Aggregate production consist of two stages is recovery and processing.
3. Basic material such as stone is recovered from a rock quarry or from the riverbed and processing is done which consist of crushing grading, washing, etc.

**Aggregate Production Equipment**

Crushers are used mainly to reduce the size of large stone or rock to smaller uniform size aggregate required for concrete mix.

Crushing consists of:

1. Pressure
2. Impact
3. Attrition
4. Combination of these operations

**Types of Crushers**

**1. Jaw Crushers**

1. It is one of the primary crushers.
2. It operates by allowing stone to flow into the space between two jaws, one of which is stationary and other is movable.

3. The distance between the two jaws decreases as the stone travels downwards under the effect of gravity and ultimately passes through the lower opening.
4. Jaw crushers operate according to the principle of pressure crushing.
5. Stone is feed between these two jaws opening of which is bigger at the top from where stone is fed and smaller at the bottom to get aggregates reduced to the required size.
6. The movable jaw exerts pressure which is required to crush the rock.

**2. Gyratory Crushers**

The Crusher unit consists of a heavy cast iron or steel frame with an eccentric shaft and driving gear in the lower part of the unit. The rock is feed into the camber at the top and as downward. Crushing is done and finally emerges through the bottom gap. It is available in sizes varying from 20cm to 200cm.

**3. Cone Crusher**

1. These crushers are used as secondary crushers.
2. They can produce large quantity of uniformly fine crushed stone aggregates.
3. It has a shorter cone with smaller inlet and outlet opening as compared to the gyratory crusher.

**4. Roll Crushers**

Roll Crushers are also one of the secondary crushers to produce additional reduction to the size of stone after the output of a quarry has been subjected to one or more stage of prior crushing.

**5. Impact Crushers**

1. Impact crusher improves the use of impact rather than pressure to crush material.
2. Hammer mill can a type of impact crusher. As the stone is feed to the mill hammer which are driven by a motor at the high speed and break the stone into pieces.
3. Rod mill is used to produce sand from crushed aggregates. If steel balls are used to give impact in place of rod, then it is named as ball mill.

**# Why are binding materials used in road constructions?**

**Ans:** Binding materials which are being used for bond between different constituents of pavement. Binding materials increase the resistance between individual elements

of mixture and increase its strength.

**Earthwork Machinery Types and Uses**

Equipment used in excavation for foundation or for collection and production of construction material is called earthwork equipment.

**# Equipment**

**a. Earthwork moving Equipment**

i. Dozer (Bulldozer, angle dozer, tree dozer) ii. Scrapper iii. Loader iv. Excavator (backhoe) v. Drag line vi. Clamshell viii. Trench digger

**b. Compacting Equipment**

i. Smooth wheel rollers ii. Vibrating rollers

iii. Pneumatic Rollers iv. Sheep foot rollers v. Rammers

**c. Leveling Equipment**

i. Grader

**d. Paving Equipment**

i. Binder Spreader ii. Aggregate Spreader

iii. Cement concrete mixer

**e. Lifting Equipment**

i. Back bone (for low road) ii. Crane (different capacity)

**f. Transporting Equipment**

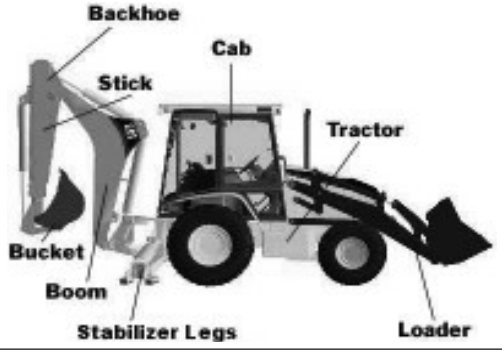
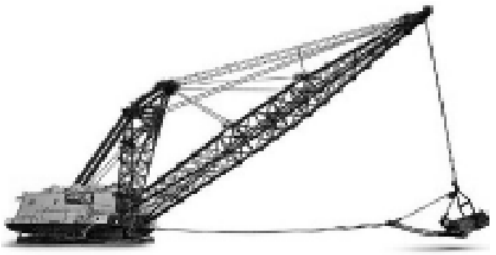
i. Dumping trucks (tipper) ii. Trucks (flat body)

iii. Mini Dumper

**g. Plants**

i. Cement concrete plant ii. Aggregate crusher plant

iii. Asphalt concrete plant iv. Washing Plant

| | |
|---|---|
|  |  |
| ***BULLDOZER*** | ***SCRAPPERS*** |
|  |  |
| ***GRADER*** | ***CLAMPSHELL*** |
|  |  |
| ***POWERSHOVEL/LOADER*** | ***EXCAVATOR*** |
|   |  |
| ***BACKHOE*** | ***DRAGLINE*** |

***BELTCONVEYOR***

***CEMENT CONCRETING***

***ASPHALT PLANT***

***TRENCHDIGGER***

***CRANE***

## Exercise

### Choose the correct answer from the given alternatives.

1. The soil becomes weak in _____

   a. Summer  b. Winter

   c. Rainy season  d. Spring season

2. Which of the following pavement has greater life?

   a. Bituminous pavements  b. Cement concrete pavements

   c. Gravel roads  d. Earth roads

3. The surface of the pavement should be _____

   a. Smooth  b. Rough

   c. Sufficient enough to resist skid  d. Very rough

4. Rough and uneven roads increase _____

   a. Vehicle cost  b. Petrol cost

   c. Accident cost  d. Vehicle operation cost

### Write short answer to the following questions.

1. What are the types of pavements? Explain them.
2. What are the general structures of pavement?
3. Explain rigid pavement.
4. Explain flexible pavement.
5. Write the uses of a surface course.
6. Explain sub grade.

### Write long answer to the following questions.

1. Differences between rigid and flexible pavement.
2. What are the general structures of pavements? Explain.
3. Explain rigid and flexible pavement.
4. Write the uses of subgrade, subbase base, and surface course.

# Unit 7 : Road Construction Technology

**Road Construction Technology**

**i. Road construction project can be divided into following phases:**

**ii. Earthwork and preparation of sub grade**

**iii. Laying of pavement**

**iv. Protection works like retaining wall and construction of drainage facilities.**

Road construction technology is the branch of engineering which deals with all kinds of activities and technologies or operations for changing existing ground to the desired shape, slope and to provide all necessary facilities for smooth, movement and efficient traffic movement and operation which also include the reconstruction of existing roads. Various activities of road construction include:

**i) Earthwork and Site Clearance**

- Site clearance
- Earthwork in filling for Embankment
- Earthwork for cutting
- Earthwork for structural foundation

**ii) Drainage Works**

- Minor bridges
- Culverts
- Cause way
- Side drain
- Surface and sub-surface drainage

**iii) Protection Works**

- Earth retaining structure
- Landslide stabilization
- Bridge protection work

**iv) Pavement Works**

- Sub-grade works
- Sub-base works
- Base work
- Surface work

**v) Miscellaneous Works**

- Traffic signs/signals/marking
- Bio-engineering works

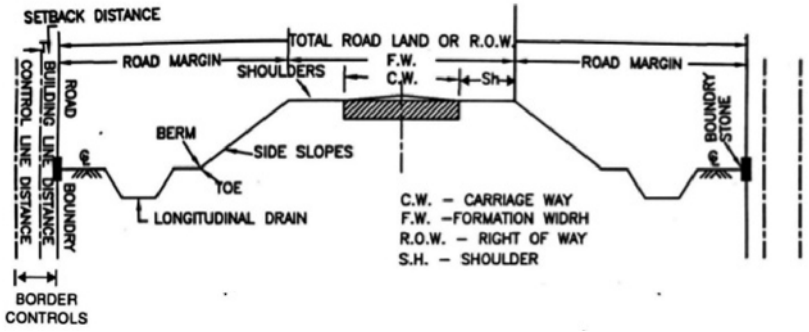



***Fig: Element of cross section.***

## 7.1 Embankment Construction: Field Procedures

1. Generally, the pavement is laid over an embankment:
2. The embankment is generally constructed using locally available soil borrowed from either side including the soil excavated for the longitudinal side drain.
3. Waste materials which are suitable for use in embankment, such as fly ash may also be used, but by strictly following the recommended design and construction methodology.
4. Generally, the original ground can serve as embankment foundation without any special treatment.
5. The sub grade is constructed using selected soil brought from approved borrow pits which fulfill the specified CBR value and other requirement.
6. The total compacted thickness of sub grade is 500 mm.
7. Suitable type of permeable materials such as crushed stones, gravel or granular soil with less percentage of fines may be used in drainage layer.
8. The pavement layers may be either components of flexible pavement or rigid

pavement as per structural design.

9. The shoulders form an important component of a highway as they give not only added stability, confinement and durability to the pavement structure but also useful to the road users for use as an emergency lane.

Components of a highway embankment are:

a. Embankment or fill

b. Subgrade

c. Drainage layer

d. Shoulders

e. Pavement layers

**Steps for Highway Construction on Embankment**

1. Remove the vegetation, roots and other organic matter along the alignment up to the bottom width of the embankment and the side drains
2. Re-compaction of the ground that supports the embankment to the specified density
3. Selected soil is spread and compacted in layers to form embankment as specified
4. Selected soil is spread and compacted in layers to form the subgrade
5. Excavation for the longitudinal side-drain
6. Construction of cross drainage layer
7. Laying of drainage layer
8. Building up the shoulder layer
9. In the case of flexible pavement, construction of base course in layers: in the case of rigid pavement, construction of lean concrete base course
10. In the case of flexible pavement, construction of bituminous binder and surface course layer. In the case of rigid pavement construction of cement concrete slab and the specified joints
11. Finishing works

## 7.2 Earthen Road Construction: Field Procedures

1. An earthen road is the cheapest type of road
2. The pavement structure is made totally from the available soil at the site
3. The performance of these roads mainly depends upon the effective maintenance and drainage

4. The type of construction largely depends upon the soil type at site. The camber provided on these roads is very steep and varies from 4.5%
5. The steep cross slope helps to keep the pavement surface free of standing water otherwise the pavement section by softening
6. The maximum cross-slope should also be limited to 5% to avoid erosion due to rainwater
7. This road may be constructed manually with hand tools or different equipment for excavation

**# Materials Required**

More clay is also harmful because it tends to swell when wet and shrink when dry.

| Soil Type | Base course | Wearing Course |
|---|---|---|
| Clay Content (%) | < 5 | 10-18 |
| Silt Content (%) | 9-32 | 5-15 |
| Sand Content (%) | 60-80 | 65-80 |

**Earthen Road Construction Procedures:**

**i. Materials**

The soil survey is carried out and suitable borrow pits are located within short distance. Material should be free from organic matter and trees shrubs, grass root and topsoils are removed before excavating earth for contruction.

**ii. Location**

The Centre line and road edges are marked on the ground along the alignment by wooden peg. The spacing of the reference peg depends on the estimated length of road construction per day.

**iii. Preparation of Subgrade**

The various process for the preparation of subgrade is:

- Site clearing
- Excavation and construction of fill to bring the road to a desired grade
- Shaping of subgrade
- Compaction before placing the pavement material

**iv. Pavement Construction**

Soil to be used in the construction of road pavement is suitably proportioned and spread on the prepared subgrade. The field moisture content is checked, and additional water is added to bring it up to optimum moisture content. The soil layer so prepared is compacted in such a way that the compacted thickness doesn't exceed 10cm.

**v. Opening to Traffic**

The compacted road is allowed to dry out for few days before opening to traffic so that the road pavement may acquire sufficient strength and stability suitable side drain is provided on both edge of road.

## 7.3 Gravel Road Construction: Field Procedures

1. Gravel roads are considered superior to earth road as they can carry heavy traffic load
2. The feather edge type is constructed over the subgrade with varying thickness to obtain the desired cross slope for the pavement surface
3. In the trench type, the subgrade is prepared by excavating shallow trench

**Materials**

Hard, Durable, strong variety of crushed stone or gravel of specified gradation is used for the road construction. (Rounded shouldn't be used. Why?) → Because of their poor interlocking.

**Equipment's**

The road can be constructed manually with hand tools or using other equipment for excavation, hauling, compaction.

**To Transport (pull or drag with force)**

❖ **Construction Procedure**

Gravel to be used for construction is stacked along the sides of the proposed road.

**Location and Preparation of Subgrade**

Compacted subgrade is prepared as in the case of earth road. Usually trench type construction technology is followed. Trench is formed to the desired depth of construction; the width of trench is made equal to that of the carriage way. The trench is brought to the desired grade and compaction of trench base is done to obtain hard. Consolidated base for the gravel layer.

**Pavement Construction**

1. Crushed gravel aggregate is placed carefully in the trench to avoid segregation.
2. Aggregate is spread with greater thickness at the Centre and less towards the edges to obtain desired camber.
3. The layer is rolled using smooth wheel rollers.
4. Some quantity of water may be sprayed to get effective compaction.

**Opening to Traffic**

Few days after the initial rolling and drying out, the road is opened to traffic proper drainage facilities should be provided.

# WBM → Water Bound Macadam

## 7.4 WBM Road Construction: filed procedures

This type of road construction is known after the name of John Macadam. Water bound macadam roads are constructed by crushed or broken stone aggregate mechanically interlocked by rolling and voids filled with screening and binding materials with the help of water.

1. Binding material → Limestone dust
2. Screening → Filler materials
3. Screening consists of aggregate of smaller size and are used to fill voids
4. Water bound Macadam is constructed in thickness ranging from 10 - 7.5 cm.
5. WBM gets deteriorated rapidly under the adverse condition of traffic and weather. Therefore, it is desirable to provide a bituminous surfacing course over the water bound macadam layer to prolong its life
6. Generally, camber of l in 36 to l in 48 provided in water bound macadam road

**4. Materials Required**

a. Coarse aggregate

b. Binding materials

c. Screenings (Filler materials)

**5. Equipment**

The equipment to be used in the construction of roads are manual tools and other equipment's like water tanker, grader and compacting equipment's.

**Construction Procedures:** Preparation of subgrade Provision of lateral confinement

1. Spreading the coarse aggregate Rolling
2. Application of screening
3. Sprinkling and wet rolling (to fill about 50% of total voids)
4. Application of binding materials Setting and drying Quality control

Construction Procedure of Water Bound Macadam (WBM) Roads

**1. Preparation of Subgrade**

Careful preparation of subgrade is necessary. The foundation layer is prepared to the required grade and camber and the dust and other loose materials are cleaned. Weak spots (depressions and potholes) in the subgrade must be corrected before the base or surface is placed and the subgrade soil is brought to a high degree of uniformity, density and stability.

**2. Spreading the Coarse Aggregate**

Coarse aggregate is stacked along the length of the road at suitable intervals on the prepared subgrade, coarse aggregate is spread uniformly to proper profile and even thickness.

**3. Rolling**

After spreading the coarse aggregate properly, rolling is done with 6 to 10 tones three wheeled rollers or vibratory rollers. Rolling is usually started from the edges and progress towards the centre. The process is repeated by rolling from the edges towards the centerline until adequate compaction is achieved.

**4. Application of Screening**

After rolling the coarse aggregate layer, screening consists of small pieces of stone is spread uniformly over it in three or more application. Spreading brooming and rolling operation are carried out at the same time and in conjunction with one another.

**5. Sprinkling and Wet Rolling (to fill about 50% of total voids)**

After light dry rolling, the surface of the layer is sprinkled with water and rolled again, sweeping is done which helps screening to enter the voids. The sprinkling and rolling are continued until all the voids are filled.

**6. Application of Binding Material (Filler)**

A suitable filler material is then applied at uniform and slow rate in two or more successive thin layer. After each application of filler materials, the surface is sprinkled with water the resulting slurry swept into the voids properly and surface rolled by a roller.

**7. Setting and Drying**

The road surface thus prepared is allowed to set overnight. If the potholes are located, then they are filled with screening or binding materials lightly sprinkled with water if necessary and rolled. The road is opened after it properly set and dry.

**8. Quality Control**

Checking of camber and grade

## 7.5 Bituminous Macadam Road Construction: Field Procedures

1. Road in which bituminous is used as binder are termed as bituminous Road.
2. Bituminous binder may be road, tars, cutback, emulsion, etc.

❖ **Types of Bituminous Construction Roads**

**1. Classification Based on Construction Technique**

- Surface dressing and seal coat
- Bituminous concrete, Bituminous Carpet, Bituminous Bound Macadam

**2. Classification Based on the Temperature of Binder**

- Hot mix
- Cold mix

**3. Classification Based on Method of Mixing**

- Road mix method
- Control plant mix method

**4. Classification Based on Texture Open Graded (premixed carpet)**

- Dense graded (bituminous concrete)

**Plants and Equipments**

1. Equipment's for heating of bitumen

2. Mechanical sprayer
3. Hand brushed Roller

**Bituminous Road Construction Procedures**

1. **Preparation of Existing Surface:** Potholes and depressions are rectified and prepared to proper profile before the treatment is done. All the dust particles or loose materials are removed, and prime coat is applied.
2. **Application of Binder:** Uniform spraying of bituminous binder is done at the specified rate on a prepared surface using mechanical sprayer.
3. **Application of Stone Chipping:** Cover materials is spread as per the requirement to cover surface uniformly
4. **Rolling of First or Final Coat:** The rolling is done with tandem roller (6 to 8 tones) starting from the edges proceeding towards the centre.
5. **Application of Binder and Stone Chipping for Second Coat:** Immediately after applying the binder to the prepared surface as per the requirements cover materials are spread. i.e. stone chipping.
6. **Rolling of Second Coat:** Rolling is done in the same way described earlier.
7. **Finishing and Opening to Traffic:** The road section is opened to traffic after 24 hours. If the road is required to open to the traffic immediately the speed of traffic shall be limited to 16 kmph.

**Seal Coat**

Seal coat is defined as a very thin surface treatment or single coat surface dressing which is either applied as a final step in the construction of certain bituminous surfaces, which have cracked or worn out.

**Purpose to Provide Seal Coat**

- To increase the resistance of skidding
- To increase the strength and bearing capacity of the existing surface.

**Otta Seal**

Otta seal is the bituminous surfacing consisting of graded aggregate ranging from natural gravels to crushed rocked in combination with relatively soft (low viscosity) binders, with or without sand cover seal.

## 7.6 Surface Dressing, Otta Seal: Field Construction Procedures

1. Preparation and cleaning of the existing surface by a mechanical broom or hand brushes and air compressor.
2. Application of prime coat
3. Spreading of binder as per specified rate of application.
4. Spreading of aggregate of specified grading as per specified
5. Rolling by two pneumatic rollers at a minimum weight of 12 tons or more at the day of constructions.
6. After the initial rolling is completed (on the day of construction) it is advantages to apply one pass
7. During the first two days after sealing, extensive rolling shall be applied by pneumatic rollers to ensure all particles embedded in the binder are properly coated.
8. After the aggregate particles are embedded into the binder, spreading of binder as per specified rate.
9. Spreading of sand as per specified rate of application.
10. Rolling with pneumatic roller till 4 weeks.
11. After 8-12 weeks second coat is executed following the above-mentioned construction steps.

## Exercise

### Choose the correct answer from the given alternatives.

1. Camber provided in WBM road is.....

   a.1 in 36 - 1 in 45 b. 1 in 24 - 1 in 36

   c. 1 in 36 - 1 in 24 d. 1 in 36 - 1 in 60

2. The main purpose of provide seal coat are.....

   a. To increase the resistance of skidding b. To increase the strength

   c. To increase bearing capacity of the existing surface

   d. All of the above

3. What do you mean by WBM?

   a. Water Bound Macadam b. Water Bound Material

   c. Water Bearing Macadam d. Water Bearing Material

4. The maximum cross-slope should also be limited to avoid erosion due to rainwater is .....

   a.2 b.3 c.4% d.5%

5. Percentage of clay content in Base Course in not greater than.....

   a. 2% b. 3% c. 4% d. 5%

### Write short answer to the following questions.

1. Explain Sprinkling and wet rolling process in WBM road.
2. Write construction procedure of gravel road.
3. Write construction procedure of bituminous pavement.
4. Write surface dressing Otta seal construction procedures.
5. Explain pavement construction procedure in gravel road.

### Write long answer to the following questions.

1. Write down Embankment construction field procedure.
2. Write down the earthen road construction procedure.
3. Explain gravel road construction procedure.
4. Define WBM road and explain its construction procedure.
5. Write down bituminous road construction procedure.
6. Explain surface dressing, otta seal construction procedure.

# Unit 8 : Low-Cost Roads

## 8.1 Introduction

The low-cost road can be defined as those roads whose cost of construction and maintenance is less. Therefore, such roads should as far as possible be constructed from locally available road construction materials using local manpower, and initially constructed in such a way that step by step improvement of road is possible without incurring any extra expenditure.

Such low-cost roads should have potentiality of subsequently being improved to higher specification as traffic intensity on the highway increases. Therefore, geometric standards of village roads should be chosen in such a way that no alternation in vertical and horizontal alignment might be required when these are to be upgraded. Further, with the increase in traffic it should be possible to strengthen the pavement in stages utilizing the existing pavement layers.

## 8.2 Types and Field Construction Technology

A typical example of stage construction is as below

**Stage-1 Land Acquisition and Road Embankment or Cutting (Formation)**

The road may at the first stage be thrown open to the traffic which may be of the order of 500 tones/day. The advantage of keeping road formation open for few seasons before upgrading is that the formation gets stabilized and chance of settlement of the soil due to subsequent heavier traffic loads are reduced. The formation width should however be for a fully developed road in view.

**Stage-2 Pavement**

The thickness of pavement may initially be to cater to the intermediate traffic needs, which at latter stage may form subbase for the main travelling surface

**Stage-3:** The strips of pavement provided under stage-2 may be widened.

**Stage-4:** The existing pavement may be improved by providing additional layer of pavement so that larger traffic can be taken care of, or the existing layer of pavement may

form the base/sub base for a rigid pavement or a bituminous carpet may be laid over this layer to upgrade road classification

Low costs roads may broadly be classified into the following categories:

1. Earth roads
2. Kankar roads
3. Gravel roads
4. Traffic bound macadam roads
5. Water bound macadam roads

The following construction practices should be reviewed for low-cost road construction:

1. Construction of roads should be done on balance approach following mass curve instead of cutting and spoils.
2. Construction of road should be done in stage wise in different years instead of one years instead of one year. By this way dispute raised at the site is managed. year 1st Yr. - 1.5m,2nd Yr- 3m, 3rd Yr.- 4.5m
3. The planning of road should be done based on decentralization without any political interference.
4. During construction local materials should be utilized
5. During construction local manpower should be utilized
7. For stabilizing the slope bio-engineering technique is used instead of civil engineering structures.
8. In combination of bio engineering technique gabion is used instead of retaining wall.
9. Soil stabilization technique should be used.
10. In case of natural water courses, causeway should be preferred instead of bridge.

11. The slope of road should be outward which avoid the provision of longitudinal side drain.
12. Water discharging from hillside to valley side is collected by the provision of catch drain with proper water management.

## 8.3 Advantages of Stage Construction

1. The formation width is stabilized and chance of settlement of the soil due to subsequent heavier traffic loads are reduced.
2. Easy for construction of first stage as well as next stage
3. Local people get maximum engaged in construction
4. Disputes arise at site can easily be managed
5. Locally available materials are used which reduce cost of construction.

## 8.4 Introduction of Bridges

A bridge is a structure built to span a physical obstacle, such as a body of water, valley, or road, without closing the way underneath. It is constructed for the purpose of providing passage over the obstacle.

**Suspension Bridge**

The bridge, which is supported by the cable so that, load acting on the bridge deck is transferred to the ground through the supported cables is called suspension bridge. In the earliest period, suspension bridges were used to construct with the cables anchored in the ground at either end of the bridge. Suspension bridges are made up of towers, anchors, main cables, suspension cables, and bridge deck. A bridge deck may consist of reinforced cement concrete or steel structure as per design and construction requirements.

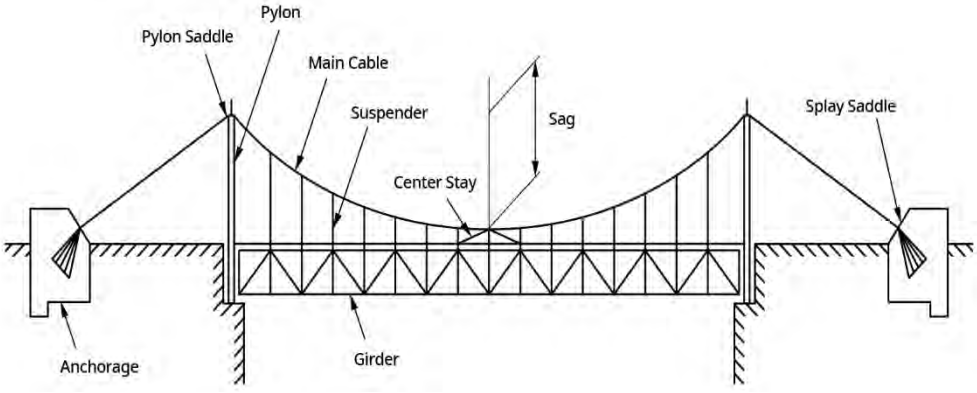



***Fig: - Component of suspension bridge***

Suspension bridge required lesser number of piers in longer span, these are aesthetically pleasant, water can be opened during construction, design is flexible, and deck section can be replaced as needed. But these are less robust than other types, large wind effects, required ongoing maintenance.

**Suspended Bridges**

The type of bridge in which load on bridge deck is transferred by the deck itself resting on the support is called suspended bridges. Most of the bridges constructed over the Nepal are of these types. To transfer the load from the desk of bridge, vertical abutment at two ends and piers at between the abutment are designed. All the load from deck are transferred to the ground through the bearing pad and abutment along with piers.

Suspended bridges are usually provided with beam of different sections as per design load. Suspended bridges are easy to construct, simple in design, economical and with minimum maintenance. But these requires pier for longer span. For economical purpose, the span is limited between the structures as far as possible. It has limited design options for appearance.

## 8.5 Components of Suspension Bridges

Suspension bridge has following components:

1. Deck
2. Girder
3. Main cable
4. Tower
5. Suspender
6. Anchorage
7. Saddle

**1. Deck**

It is the portion of bridge in which, vehicle or passenger move. It is supported on the girder or beam or rope/cable based on the type of bridge.

**2. Girder**

Girders are longitudinal structures which are supported by the cables at the desired locations. Girder supports and distribute the vehicle loads. Bridge girder may made up of Reinforced concrete or steel materials.

**3. Main cable**

Main cable are the tension members of suspension bridges that are named as ropes, cable wire or chains. The main cable cannot sustain tension and compression and can support only axial load.

**4. Towers**

Towers of suspension bridge transfer load from main cable to the foundation. Towers are made up of steel and concrete materials. The main cable is attached at the saddle of the tower and to the deck of bridge. The cable carries load from deck and transmit to the saddle of tower. Through the saddle, load will be transmitted to the ground safely. The shape of tower is limited due to limitation of construction method.

**5. Suspender**

Suspenders are the cables that connects bridge deck to the main cable. Generally, two types of suspenders are used in suspension bridge. Center fit rope cores and parallel. Wire stand are these type. The suspender helps for fixing the position of bridge deck to its designed position. It also takes load from the deck and transfers to the main cable.

**6. Anchorage**

Anchorage are the structures that transmit the horizontal as well as vertical loads from main cable to the ground. Normally, gravity-type anchorages, tunnel-type anchorages, and rock anchorages are used as anchorage

**7. Saddle**

Saddle is the top portion of the tower and anchor block which directly supports the main cable. Saddle supported on the tower is called saddle support and that supported in anchorage is called splay support.

**Components of Suspended Bridges**

Following are the major components of suspended bridges:

1. Deck
2. Girder
3. Bearing
4. Abutment
5. Piers

6. Foundation

**1. Deck**

It is the portion of bridge in which, vehicle or passenger move. It is supported on the girder or beam or rope/cable based on the type of bridge.

**2. Girder**

It is a part of superstructure, which consists of longitudinal structural members supported on abutment and piers.

**3. Bearing**

Bearing is the device which transfer load from the girder to the abutment and piers evenly. It is provided at the junction between bridge girder and abutment and pier cap. Bearing also permit controlled movement of girder and decreases the stress involved. In bridge, bearings are highly important for the transmission of the imposed loads particularly when abutment and pier have not been constructed to withstand the loads directly. Large variety of bearings have been developed. Selection of type of bearing is done based on the several factors such as types of loadings, geometry, and dimensions of the bridge, the displacement and deflection, availability of the materials, financial resources available, clearance available, maintenance criteria, etc.

**4. Abutment**

It is part of substructure of bridge which supports the bridge girder and takes load from the girder then transfers it to the foundation. It is vertical structure which may constructed of reinforced concrete or stone masonry or brick masonry. Different types of abutments are in use. It is constructed ai the ends of bridge girder.

**5. Piers**

It is also substructure of bridge which supports the superstructure and transfers load coming from superstructure to the foundation safely. Bridge piers are used to construct between the abutments at the designed spacing. Piers may be constructed with cement concrete or brick masonry or stone masonry based on the size of bridge and size of river/stream. A cap is constructed at the top of pier which takes load from bridge girder without failure and reduces the risk of upward punching during loading. Solis as well as hollow cylindrical piers are mostly used in bridge construction.

## 6. Foundation

It is the lower most part of bridge, which transmit the load coming from piers and abutment to the ground safely. Generally, foundation is flatter than that of the pier size, which minimizes the rick of punching. Foundation must be rest on stable and hard surface. Bridge foundation must be rest rock bed or hard soil stratum. The depth of foundation shall be made sufficiently deep to get hard soil stratum and to minimize scouring problem of river water.

# Exercises

## Choose the correct answer from the given alternatives.

1. The low-cost road can be defined as those roads whose.....
   a. Cost of construction and maintenance is high
   b. Cost of construction and maintenance is less
   c. Cost of construction is high, and maintenance is less
   d. Cost of construction is less, and maintenance is high

2. Low costs roads may broadly be classified into.....
   a. Two b. Three c. Four d. Five

3. Which one of the Main Components of Suspension Bridges is.....?
   a. Tower b. Girder c. Deck d. Suspender

4. The Function of Foundation in Suspended Bridges is.....
   a. Transmits the load coming from Tower and abutment to the ground safely
   b. Transmits the load coming from piers and abutment to the ground safely
   c. Transmits the load coming from Deck and Tower to the ground safely
   d. Transmits the load coming from Girder and Foundation to the ground safely.

## Write short answer to the following questions.

1. What is low-cost road?
2. What do you mean by stage construction?
3. Write any three examples of low-cost roads.

## Write long answer to the following questions.

1. Write a typical example of low-cost road
2. Write the importance of low-cost road in the context of Nepal

# Unit 9 : Hill Road

**Definition**

A hill road may be defined as one which passes through the area with cross slope of 25% or more.

| Terrain Classification | | Cross Slope (%) |
|---|---|---|
| i) | Plain | 0 to 10 |
| ii) | Rolling | Greater than 10 less than 25 |
| iii) | Mountainous | Greater than 25 up to 60 |
| iv) | Steep | Greater than 80 |

***Figure; hill road with hair pin bends***

## 9.1 Importance and Special Considerations of Hill Roads

1. In order to connect the town and villages located at the foot hills to those on the top of the hill and also to connect the intermediate village
2. Due to unbalanced productivity of land makes the people of hilly area underprivileged for the overall economic development of nation hilly road is

important

3. Construction of hill road is important not only for economic consideration but it is also associated with the social justification for providing facilities to underprivileged mass of the country
4. Hilly areas are rich in natural resources such as medicinal herb, shrubs. So construction of hill road is most important

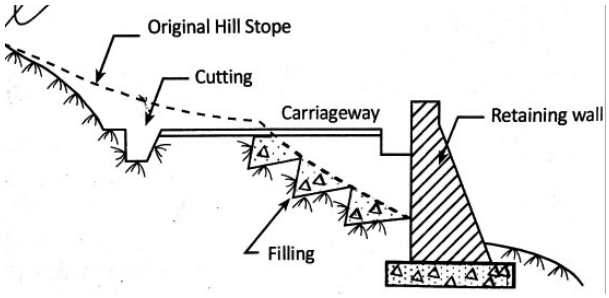



***Fig: Typical Cross- Section of Hill Road***

**Special Considerations of Hill Road**

1. Selection of road alignment
2. Geometric design (gradient and hair pin bends)
3. Cross-section design
4. Design and drainage structure (special structure may require)

**Selection of Road Alignment**

1. The requirement of hill road is decided based on administrative, developmental, other needs and obligatory points to be connected by the road.
2. The main aim is to establish a safe, easy, short and economical line of alignment.
3. The route should avoid the introduction of hair pin bends as far as possible. If such a situation become inevitable, the number of hair pin bends should be reduced.
4. The selection of road alignment in mountainous and hilly area is affected by following factors:
   a. Temperature
   b. Rainfall
   c. Atmospheric Pressure
   d. Geological section

*** Survey Method in Hill Road should follow Following Sequence**

a. Reconnaissance
b. Preliminary survey
c. Detailed survey
d. Center line
e. Final Location of survey

**Geometric Design (gradient and hair pin bends)**

Improvement of features like grade and curvature at a later stage can be very expensive and sometimes be impossible

So, ultimate requirement of geometric is most important design.

**# National Highways and State Highways**

| | Carriage way width | Shoulder width | Roadway width |
|---|---|---|---|
| Single Lane | 3.75m | 2 x 1.25m | 6.25m |
| Double Lane | 7m | 2 x 0.9m | 8.8m |
| Village roads | 3m | 2 x 0.5 m | 4 m |

**# Super Elevation**

Maximum super elevation for hill road is 10%. On snow bound area is limited to 7%.

Development of cross-section in stages is technically feasible but this should be decided only after careful consideration since hill roads need a lot of protective and drainage works like retaining walls, slope stabilization wall, drain of various categories, etc.

**# Cross-Section Design**

The cross-section of a road in hilly terrain is determined by the original ground slope of site, the slope of the road formation, width of roadways, side drain size and shape and so on. Various configuration of road cross-section includes.

1. Cut and fill
2. Bench type
3. Box cutting
4. Embankment with retaining walls
5. Semi bridge

6. Semi tunnel
7. Platforms

- **Design of Drainage Structure (Special Structure may require)**
  a. **Drainage of water from hill slope:** → through Catch water drains
  b. **Road side drain:** → Only side of road → Only on one side because due to limitation of formation width
  c. **Cross drainage:** → Through pipe culvert
  d. **Sub surface drainage:** → Changes in moisture content of subgrade are caused by fluctuations in ground water table, seepage flow and percolation of rain water.

     One major problem in hill roads are seepage flow which can be control by sub-surface drainage.

     Drainage of water from hill slope roadside drain, cross drainage structure and sub-surface drainage are most important requirement of drainage structure.

## 9.2 Terminologies Used in Hill Roads

The terminologies used in hill roads are explained as below:

**1. Drainage**

The facility provided to remove excess water generated on the road surface as well as its surrounding is called drainage. In general, water should be drained away from the road and ground surface as well as from under the surface and subsurface drainage systems. Water is drained from the road surface with adequate camber of both the carriageway and the shoulder. Roadside drains are provided in all cut sections to remove water in the longitudinal direction. Intercepting or catch water drains are placed on back of the top of cut slopes to intercept surface water. Distance of these drains from the edge of the cutting should not be less than 5m. Flumes are provided to carry collected water down deep cuts or high fill slopes. Roadside drains should be provided with minimum 0.5% longitudinal grade. Generally trapezoidal shape of drains is preferred.

Subsurface water table should always be kept 1 to 1.2 m below the subgrade level to protect pavement layers from excessive moisture. To save road subgrade from detrimental effects of moisture from the capillary rise of water a layer of granular materials is provided between the subgrade and the highest level of subsurface water.

**2. Cross-Slope**

The geometric feature of the highway pavement, which is provided for the proper drainage of the carriageway is called cross slope. It is also called camber. In curves of hill road, unidirectional cross slope is provided. As per requirement, some sections of hill roads are provided with unidirectional cross slope for drainage purpose. In this case the adverse effect of negative camber on movement of vehicles on curves should be properly checked. In all straight section of roads, cross slope shall be provided as under:

| Pavement type | Cement concrete | Bituminous | Gravel | Earthen |
|---|---|---|---|---|
| Cross slope % | 1.5 to 2 | 2.5 | 4.0 | 5.0 |

**3. Grade in Hill Road**

The rising or falling along the length of road with respect to horizontal is called gradient. Depending upon the type of terrain and height above mean sea level, suitable values of ruling gradient, limiting gradient and exceptional gradient are to be adopted and grade compensation may be provided on chapter of horizontal curves. Maximum gradient in hill roads is limited to 12% in straight portion and 7% in curved portion. Minimum longitudinal gradients for longitudinal drainage purpose are 0.5%

**4. Hair-Pin-Bend**

In hilly areas it may become difficult to avoid bends where the direction of the road reverses. The curve in a hill road which changes its direction through an angle of 180 or so, down the hill on the same side is known as hair-pin bend. Due to the shape of curve to change direction in higher gradient, hair pin bends are introduced. The shape of curve is line hair pin and named as same. The design criteria for hair pin bend will be as under:

Minimum design speed = 20 km/h

Minimum radius of curvature = 15 m

Minimum length of transition curve = 15 m

Maximum longitudinal gradient = 4%

Maximum superelevation = 10%

## 9.3 Special Structure in Hill Roads

1. Retaining wall
2. Breast wall (which is use for against the slipping surface)
3. Revetment wall
4. Toe wall
5. Slope protection works

### 1. Retaining Wall

The wall which provides adequate support and stability to the road way and to the slope is known as retaining wall.

- They are also provided to retain the earth mass.
- In a road where water gets overflows in such as case also retaining wall is provided.
- Retaining wall is provided to achieve roadway width, where cutting into hill is not economical.

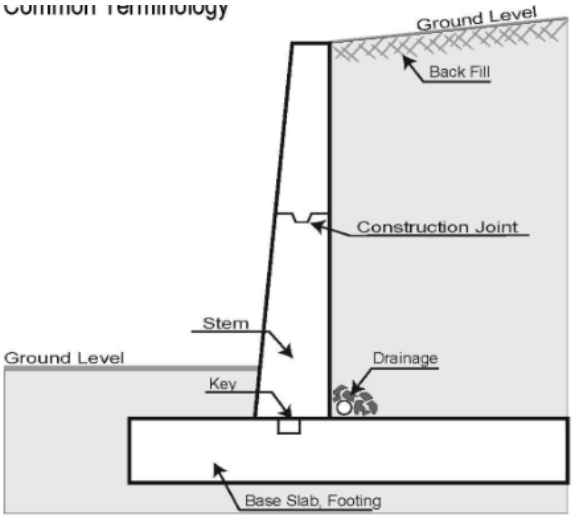



***Fig: Retaining wall***

### 2. Breast Wall (which is use for against the slipping surface)

- A low wall built to retain the face of natural bank of earth is called breast wall.
- Breast wall is generally used in slipping surfaces.
- Breast walls resist the lateral pressure of earth mass
- Breast walls prevent of hill slides under the action of weather and rainwater

flowing over hill slope.

**3. Revetment walls**

- The embankment slopes are normally protected with rough stone pitching about 0.3 m thick in order to avoid erosion as shown in figure. If sloping length is too long it is preferable to construct a to wall as shown in fig b. to support the embankment.
- Where the cutting slope is steep and contains soil, which is loose or can get scoured, slips are likely to occur. In such location, revetment walls of dry-stone masonry are constructed to retain the soil on the cutting side to prevent occurrence or any such slips.

***Fig: Revetment wall***

**4. Toe Wall**

Toe wall are used to bound soil between two different elevations. If the slopping length is too long it is preferable to construct toe wall as to support the embankment.

A low retaining walls especially an embankment wall in a rail road cut.

***Fig: Toe Wall***

## 5. Slope Protection Works

Supporting the unstable slope by the application of rock bolts, soil nails and ground anchors is known as slope protection work. Reducing pore - water pressure in the slope by surface and sub surface drainage.

Protection from small, collapse, erosion and weathering by application of pitching works.

Slope protection work for rock fall prevention. Generally Bioengineering works are carried out for slope protection works. Water management in both the cut and fill slopes is most important to protect the slope for erosion.

## Exercise

### Choose the correct answer from the given alternatives.

1. Minimum length of transition curve in hair pin bend is.....

   a.15m b.20m c.25m d.30m

2. Cross slope in earthen road is equal to

   a.2% b.3% c.4% d.5%

3. The hill road should be aligned _____

   a. Stable side b. Unstable side

   c. Based on economy d. Based on population

4. Which is the most common feature in hill road?

   a. U turn b. Hair pin bend

   c. Speed limit d. SSD

5. What is the most important structure in a hill road?

   a. Retaining wall b. Pavement

   c. Drainage d. Security force

6. Cross slope in earthen roads is equal to.....

   a. 2% b. 3% c. 4% d. 5%

7. Roadway width of Single Lane roads?

   a. 3.25m b. 4.25m c. 5.25m d. 6.25m

### Write short answer to the following questions.

1. Draw retaining wall with neat sketch with component.

### Write long answer to the following questions.

1. Write down special consideration of hill road.
2. Write down about slope protection works.
3. Explain

   a. Toe wall

   b. Revetment wall

4. Explain

   a. Retaining wall

   b. Breast wall

# Unit 10 : NRS and Feeder Road Guidelines

## 10.1 Carriageway

a. The standard width of carriageway shall be as shown on the following table. Total width of pavement shall be determined based on the volume of the traffic and capacity of each lane as given on art. 5.15

***Table 10-1Width of Carriageways, m Single Lane Road Intermediate Lane Multilane pavements width per lane 3.75 (up to 3.0 m in difficult terrain)***

b. In case of single lane roads, it is recommended to have two treated shoulders on either side to make a total width of 5.5m of treated surface.

## 10.2 Shoulder

a. The width of shoulders on either side of the carriageway shall be at least 0.75m. Recommended width of shoulder for various classes of roads is given below in Table 11-2.

b. For protection of pavement from water percolating under it from shoulder it is recommended to treat at least a 0.50-0.75m wide strip of shoulder near the edge of the pavement with impervious to water surfacing.

c. If a small gap(<1m) of untreated shoulder is formed between the edge of the pavement and edge of the side drain in hill roads it is recommended to treat this gap with appropriate surface treatment.

d. For mountainous and steep terrains, the above values can be reduced to a minimum value for a lower class of the road but not less than 0.75m.

e. It is desirable that the color and texture of shoulders be different from those of the carriageway.

f. This contrast serves to clearly always define the carriage way, particularly at night and during inclement weather, while discouraging the use of shoulders as additional through lanes.

g. Very wide shoulders (more than 3.75m wide) are also not desirable due to tendency of vehicles misusing it as a carriageway.

*Table 10-2 Width of Shoulders, m*

| Road Class | Minimum shoulder width, m |
|---|---|
| Class I | 3.75m |
| Class II | 2.5m |
| Class III | 2.0m |
| Class IV | 1.5m |

## 10.3 Medians

a. For roads with 4 or more lanes, it is recommended to provide medians or traffic separators. Medians should be as wide as possible.

b. A minimum median width of 5m is recommended. But a width of 3m can be adopted in areas where land is restricted.

c. In mountainous and steep terrains maximum possible width of median strip by the topography should be provided. In such situations simple barriers may be provided to function as a median or individual carriageways could be designed at different levels.

d. On long bridges and via ducts, the width of the median may be reduced to 1.5m, but in no case this should be less than 1.2m. 16

e. The median should be of uniform width in a particular section of the highway. However, where changes are unavoidable, a transition of 1 in 20 must be provided.

## 10.4 Formation or Roadway Width

a. Formation width shall be a total of widths of carriageways, medians and shoulders as discussed in previous paragraphs.

## 10.5 Camber

a. All straight sections of roads shall have a camber or crossfall as given on the Table 11-3.

b. On roads with undivided carriageways the camber shall be on both directions from the centre line of the road. On roads with divided carriageways unidirectional camber can be provided.

c. However, on some sections of hill roads with undivided carriageway a unidirectional camber can be adopted. In this case the adverse effect of negative

camber on movement of vehicles on curves should be properly checked.

d. On straight sections of roads, shoulders should have a higher crossfall than that of the carriageway by 0.5%.

***Table 10-3 Camber, %***

| S.N. | Pavement type | Camber, % |
|---|---|---|
| 1 | Cement Concrete Road | 1.7-2% |
| 2 | Bituminous Road | 2-2.5% |
| 3 | Gravel Road | 4% |
| 4 | Earthen Road | 5% |

## 10.6 Superelevation

a. Superelevation is provided on horizontal curves.

Where, e-value of superelevation, m/m

$e+f = V^2/127R$

R-Radius of horizontal curve V-Design Speed, km/h

f-co-efficient of lateral friction, depends on the vehicle speed and taken as

***Table 24-4***

b. Maximum superelevation to be provided is limited to:

- In plain and rolling terrain 7%
- In snow bound areas 7%
- In hilly areas not bound by snows 10%

c. Minimum value of superelevation should be equal to the rate of camber of the pavement.

d. The rate of introduction of superelevation (i.e. longitudinal grade developed at the pavement edge compared to through grade along the Centre line) should be such as not to cause discomfort to travelers or to make the road unsightly.

e. Rate of change of the outer edge of the pavement should not be steeper than 1 in 150 in plain and rolling terrain and 1 in 60 in mountainous and steep terrain in comparison with the grade of the Centre line.

## 10.7 Side Slopes

a. Side slopes of embankment and cuttings depend on the type of fill/ cut materials and height/depth of filling/cutting.

b. Recommended side slopes for embankments are given below. But wherever possible flatter slopes are recommended for aesthetic reason and traffic safety.

## 1.9 Right of Way and Clearances

### 10.9.1 Right of Way

a. Right of way for different types of roads shall be as follows:

***Table 10-6: Right of way Road Type Total Right of Way***

| | |
|---|---|
| National Highways | 50m |
| Feeder Roads | 30 m |
| District Roads | 20m |

### 10.9.2 Lateral Clearances

a. For a single carriageway road that goes through an underpass, whole width of the roadway (carriageway plus shoulder widths) should be cleared in lateral direction.

b. If footpaths are provided minimum lateral clearance should be width of footpath plus 1.0 m. 20

c. On roads with divided carriageway, left hand side lateral clearance should be as given on (a.) and (b.) above.

d. Right hand side clearance should be 2.0 m (desirable) with 1.5m minimum.

### 10.9.3 Vertical Clearances

e. A vertical clearance of 5.0m measured from the crown of the road surface shall be provided for whole roadway width on all roads. No obstructions shall be made on this space.

**Surface Drainage**

a. Water is drained from the road surface with adequate camber of both the carriageway and the shoulder.

b. Roadside drains are provided in all cut sections to remove water in the longitudinal direction.

c. Toe-of-slope road side drains are constructed in low fill (<0.8m filling height) sections to convey water away to water courses

d. Intercepting or catch water drains are placed on back of the top of cut slopes to intercept surface water. Distance of these drains from the edge of the cutting should not be less than 5m.

e. Flumes are provided to carry collected water down deep cuts or high fill slopes.

f. Drains should be provided with minimum 0.5% longitudinal grade.

g. Trapezoidal shape of drains is preferred.

h. For calculating design discharge on roadside drains following return periods should be taken.

## Exercise

### Choose the correct answer from the given alternatives.

1. ROW of feeder road According to NRS 2070 is.....

   a.15m b.20m c.50m d.30m

2. Maximum superelevation in snow bound area is.....

   a.5% b.7% c.10% d.12%

### Write short answer to the following questions.

1. Define super elevation and sight distance.
2. Write about the super elevation and its important in highway design.

### Write long answer to the following questions.

1. Explain the different type of camber.

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