

सरकारी कार्यालयहरूको भौतिक पूर्वाधार र

स्तरीकृत विन्यास- २०८३



नेपाल सरकार

पूर्वाधार विकास मन्त्रालय

सिंहदरबार, काठमाडौं

विषय सूची

१. प्रस्तावना:.....	1
परिच्छेद – १: प्रारम्भिक	2
१. संक्षिप्त नाम र प्रारम्भ	2
२. परिभाषा.....	2
परिच्छेद – २: आधारभूत सिद्धान्त तथा साझा मापदण्ड	2
१. स्थान छनोट तथा पहुँच.....	3
२. भवन संरचना	5
३. कार्यात्मक विन्यास	5
४. समावेशी पहुँच	7
५. सूचना तथा प्रविधि पूर्वाधार.....	11
६. स्वास्थ्य तथा सरसफाइ.....	13
७. वातावरणीय दिगोपन.....	15
९. स्तरीकृत डिजाइन.....	16
१०. सहकार्य र उत्पादकत्वको कार्यसंस्कृति प्रवर्द्धन	16
परिच्छेद ३: सरकारी कार्यालयहरूमा हुने स्थानहरू	19
१. सरकारी कार्यालय भवन भित्र हुनुपर्ने स्थानहरू.....	19
२. सरकारी कार्यालय परिसरभित्र हुनुपर्ने बाह्य स्थानहरू तथा सुविधाहरू	24
परिच्छेद ४: विविध	27
अनुसूची १: कार्यकक्षको वर्गीकरण र मापदण्ड	29
क) उपप्रधानमन्त्री/मन्त्री/राज्यमन्त्रीको कार्यकक्ष	29
ख) सचिव (विशिष्ट श्रेणी) को कार्यकक्ष	30
ग) रा.प. प्रथम(सहसचिव) श्रेणीका विभागीय प्रमुख/महानिर्देशक/आयोजना/कार्यालय प्रमुखको कार्यकक्ष	31
घ) सहसचिव (रा.प. प्रथम श्रेणी) को कार्यकक्ष	32

ड) उपसचिव (रा.प. द्वितीय श्रेणी) वा अधिकृत (रा.प. तृतीय श्रेणी) को आयोजना प्रमुख/ कार्यालय प्रमुखको कार्यकक्ष	33
च) उपसचिव (रा.प. द्वितीय श्रेणी)को कार्यकक्ष	34
छ) अधिकृत (रा.प. तृतीय श्रेणी) को कार्यकक्ष	35
ज) ना.सु वा सो सरहका कार्यालय प्रमुखको कार्यकक्ष	36
झ) अन्य कर्मचारीहरू- ना.सु. र खरिदार (रा.प. अनङ्कित) को कार्यकक्ष	36
ञ) कार्यालय सहयोगी/चालकको कार्यकक्ष	37
अनुसूची २: हरित भवन मापदण्ड (Green Building Guidelines)	38
अनुसूची ३: मार्गदर्शन (Signage) प्रयोगको मापदण्ड	226

१. प्रस्तावना:

नेपालको सार्वजनिक प्रशासन र सेवा प्रवाहलाई जनमुखी एवं नतिजामुखी बनाउन तथा कार्यालयहरूको उद्देश्य हासिल गर्न राष्ट्रसेवक कर्मचारीहरूका लागि पर्याप्त, सुरक्षित, सहज, व्यवस्थित र सम्मानजनक कार्यस्थल हुनु आवश्यक छ। एकातिर, जनतासँग प्रत्यक्ष सरोकार हुने सरकारी कार्यालयहरूमा अत्यधिक भीडभाड हुने गर्दछ भने अर्कातिर कार्यालयभित्र पर्याप्त सङ्केत चिह्न र मार्गदर्शनको अभावमा त्यहाँ पुगेका सर्वसाधारणहरू अलमल भई सेवा प्राप्त गर्न निकै कठिनाई हुने गर्दछ। कहाँ जाने, कसलाई भेट्ने र के प्रक्रिया अपनाउने भन्ने विषयमा जनसाधारण प्रायः अन्योलमा रहने गर्दछन्। अर्कातिर, कर्मचारीहरूको अधिकांश समय कार्यालयमै व्यतीत हुने भए तापनि हाल सरकारी कार्यालयहरूको भौतिक पूर्वाधार, कार्यक्षेत्रको क्षेत्रफल र उपलब्ध सुविधाहरूमा एकरूपता नहुँदा कार्यसम्पादन र सेवा प्रवाहमा प्रत्यक्ष असर परिरहेको छ। तसर्थ सरकारी कार्यालय भवनहरू सर्वसाधारण नागरिक तथा कर्मचारीहरू दुवै सम्बद्ध पक्षहरूका लागि उपयुक्त हुन आवश्यक हुन्छ।

समान तह र समान जिम्मेवारीमा रहेका पदाधिकारी एवं कर्मचारीहरू बीच कार्यक्षेत्रको क्षेत्रफलमा रहेको विद्यमान असमानतालाई क्रमशः हटाई समतामूलक कार्यस्थलको अवधारणालाई पूर्णतः आत्मसाथ गर्नु आजको आवश्यकता हो। आधुनिक समयको माग अनुरूप सरकारी सेवालाई प्रविधिमैत्री बनाई ई-शासन (डिजिटल गभर्नेन्स) को मर्मलाई व्यवहारमा उतार्न तथा उपलब्ध भौतिक स्रोत र स्थानको वैज्ञानिक एवं अधिकतम उपयोग गरी प्रशासनिक खर्चमा मितव्ययिता कायम गर्नु अपरिहार्य देखिएको छ। सबै प्रकारका सरकारी कार्यालयहरूको कार्यप्रकृति र सेवाग्राहीको चाप एउटै नहुने हुँदा, राज्यको सीमित स्रोतसाधनको उच्चतम सदुपयोग गर्न सबै भवनहरूलाई एउटै ढाँचामा ढालिनुको सट्टा कार्यालयहरूको प्रकृतिअनुसार समूहीकरण गरी सोही अनुरूपको भौतिक पूर्वाधार र स्तरीकृत विन्यास तय गर्नु आवश्यक छ।

सरकारी कार्यालयहरूमा स्तरीकृत विन्यास (Standard Layout) र मापदण्डयुक्त भौतिक पूर्वाधारको सुनिश्चितता गर्दा कार्यालयको विशिष्ट संस्थागत पहिचान कायम हुने, कार्यस्थल पारदर्शी हुने र सेवाग्राहीले सुलभ एवं छिटो-छरितो सेवा प्राप्त गर्ने वातावरण निर्माण भई सुशासनको प्रत्याभूति हुनेछ। साथै, भौतिक सुविधाहरूको न्यायोचित र सन्तुलित वितरणले पदाधिकारीहरूको सार्वजनिक छवि र कर्मचारीहरूको कार्यक्षमतामा समेत अभिवृद्धि पुग्ने देखिएकोले; तथा नेपाल सरकारका विभिन्न मन्त्रालय, विभाग र अन्तर्गतका कार्यालय तथा आयोजनाहरूमा कार्यरत पदाधिकारी र कर्मचारीहरूको तहगत आवश्यकता, पदको गरिमा र कार्यप्रकृति अनुसार कार्यक्षेत्रको क्षेत्रफल र भौतिक सुविधाहरूमा एकरूपता ल्याउन वाञ्छनीय भएकोले; पूर्वाधार विकास मन्त्रालयद्वारा तयार गरिएको यो "सरकारी कार्यालयहरूको भौतिक पूर्वाधार र स्तरीकृत विन्यास- २०८३" नेपाल सरकार (मन्त्रिपरिषद्) बाट स्वीकृत गरी लागू गरिएको छ।

परिच्छेद – १: प्रारम्भिक

१. संक्षिप्त नाम र प्रारम्भ

१) यस मापदण्डको नाम "सरकारी कार्यालयहरूको भौतिक पूर्वाधार र स्तरीकृत विन्यास- २०८३" रहेको छ ।

२) यो मापदण्ड स्वीकृत भएको मितिबाट लागू हुनेछ ।

२. परिभाषा

विषय वा प्रसङ्गले अर्को अर्थ नलागेमा यस मापदण्डमा प्रयोग गरिएका निम्न शब्दको अर्थ निम्नानुसार हुनेछ:

क) "मन्त्रालय" भन्नाले नेपाल सरकारका मन्त्रालयलाई सम्झनु पर्दछ ।

ख) "विभाग" भन्नाले मन्त्रालय अन्तर्गत विभिन्न विभागहरू सम्झनु पर्दछ ।

ग) "आयोजना कार्यालय" भन्नाले विभाग मातहतका आयोजना कार्यालयहरूलाई सम्झनु पर्दछ ।

घ) "पदाधिकारी" भन्नाले नेपाल सरकारको मन्त्री, राज्यमन्त्री भन्ने सम्झनु पर्दछ ।

ङ) "सेवाग्राही" भन्नाले कार्यालयको सेवा माग गर्ने वा उपभोग गर्ने व्यक्तिलाई सम्झनु पर्दछ ।

च) "कार्यालयको कार्यप्रकृति" भन्नाले सम्बन्धित निकायले सम्पादन गर्ने मुख्य कार्य (जस्तै: प्रत्यक्ष सार्वजनिक सेवा प्रवाह, नीति निर्माण, प्राविधिक आयोजना कार्यान्वयन, अनुसन्धान आदि) र सो कार्यालयमा दैनिक रूपमा आउने सेवाग्राहीको चापको अवस्थालाई सम्झनुपर्दछ।

छ) "श्रेणी" भन्नाले प्रचलित निजामती सेवा ऐन बमोजिम तोकिएका राजपत्राङ्कित वा राजपत्रअनङ्कित कर्मचारीका दर्जा /श्रेणीहरू सम्झनु पर्दछ र सो शब्दले सो सरहका तह वा स्तरलाई समेत जनाउँछ।

ज) "मापदण्ड" भन्नाले यस "सरकारी कार्यालयहरूको भौतिक पूर्वाधार र स्तरीकृत विन्यास- २०८३" लाई सम्झनु पर्दछ।

परिच्छेद – २: आधारभूत सिद्धान्त तथा साझा मापदण्ड

सरकारी कार्यालयहरूमा सार्वजनिक सेवा प्रवाहलाई प्रभावकारी, नतिजामुखी र पारदर्शी बनाउनु यसको मुख्य उद्देश्य हो। साथै, कार्यस्थललाई सुरक्षित, व्यवस्थित, समावेशी र आधुनिक प्रविधिमैत्री बनाई कर्मचारीहरूको कार्य उत्पादकत्व बढाउन उत्कृष्ट वातावरण प्रदान गर्नु यसको अर्को लक्ष्य हो।

सरकारी कार्यालय भवन तथा परिसरलाई सेवाग्राही मैत्री बनाउन र समावेशी अनुभव प्रदान गर्न केही आधारभूत सिद्धान्तहरूको आवश्यकता पर्दछ। हरेक सरकारी कार्यालयको स्थान, आवश्यकता र वातावरण फरक-फरक हुने हुँदा एउटै समस्याको समाधान विभिन्न आर्किटेक्ट वा इन्जिनियरले फरक-फरक ढङ्गले दिन सक्छन्। यसै तथ्यलाई ध्यानमा राख्दै, डिजाइन कार्यमा आर्किटेक्टलाई पूर्ण स्वतन्त्रता दिइएको छ। डिजाइनको सिर्जनशीलतामा कुनै रोकावट नआओस् भनेर यसमा पूर्व-निर्धारित नक्साहरू राखिएका

छैनन्। बरु, डिजाइनरको कला र व्यावसायिकताको सम्मान गर्दै, तोकिएका मापदण्डभित्र रहेर आवश्यकता अनुसारको उत्कृष्ट डिजाइन तयार गर्न प्रोत्साहन गरिएको छ।

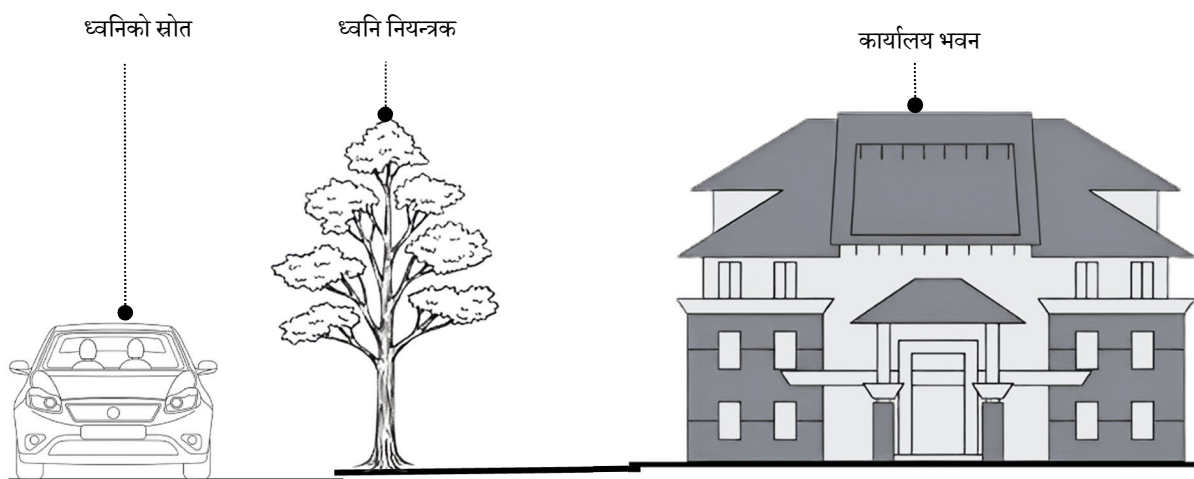
सरकारी भवन निर्माण र आन्तरिक विन्यास गर्दा निम्न १० वटा आधारभूत स्तम्भहरूलाई पालना हुनु पर्नेछ।

१. स्थान छनोट तथा पहुँच

सरकारी कार्यालयको लागि स्थान छनोट गर्दा देहाय अनुसारको क्षेत्र छनोट गर्नुपर्नेछ।

१.१ सार्वजनिक यातायात तथा सार्वजनिक खुला क्षेत्रबाट सजिलै पुग्न सकिने स्थान हुनुपर्नेछ। आगजनी, भूकम्प तथा अन्य विपद्को समयमा सरकारी कार्यालयमा कार्यरत कर्मचारी तथा सो भवनमा रहेका सेवाग्राहीहरूको तत्काल निकासको लागि सार्वजनिक खुला क्षेत्र नजिक भएमा जोखिम न्यून गर्न सक्ने भएकोले स्थान छनोट गर्दा सार्वजनिक खुला क्षेत्रको दूरी समेतलाई ध्यान दिनु पर्नेछ। यसो गर्दा, सार्वजनिक खुला क्षेत्र कार्यालयको परिसर भित्र वा बाहिर मान्नु बाधा पुग्ने छैन।

१.२ भौगोलिक वा प्राविधिक रूपमा असम्भव भएको अवस्थामा बाहेक सडक सञ्जालमा विभिन्न मार्गहरू एक-अर्कासँग जोडिने वा बाटो काट्ने बिन्दुहरू (ट्राफिक नोडहरू) नजिक पर्ने स्थान हुनुपर्नेछ। सेवाग्राहीको सहज पहुँच र हिँड्ने दूरी कम गर्नका लागि सरकारी कार्यालयहरू मुख्य ट्राफिक नोड वा ट्रान्जिट बिन्दुको नजिक हुनु आवश्यक छ। यद्यपि, सडकको कोलाहलले कार्यालयको आन्तरिक वातावरणमा बाधा नपुगोस् भन्नका लागि भवनलाई सडकको बिल्कुलै छेउमा भने निर्माण गरिनुहुँदैन। यदि सडक किनारमै निर्माण गर्नुपर्ने अवस्था रहेमा, भवनको वास्तुकला डिजाइन तयार पार्दा नै बाहिरी ध्वनि प्रदूषणलाई न्यूनीकरण गर्ने वा छेक्ने उपयुक्त व्यवस्था मिलाउनुपर्नेछ।

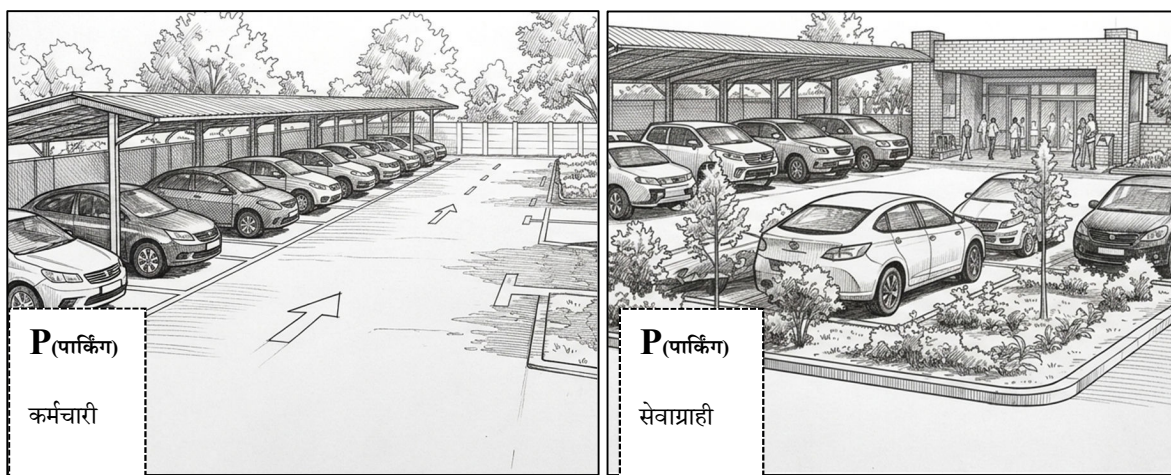


चित्र १: सडकबाट अति नजिकका कार्यालयमा ध्वनि नियन्त्रण प्रणालीको नमुना

१.३ सबै नागरिक, विशेषगरी फरक क्षमता भएका व्यक्तिहरूका लागि पहुँचयोग्य स्थान हुनुपर्नेछ, वा सहजै पहुँचयोग्य बनाउन सकिने प्रकृतिको हुनुपर्नेछ। कार्यालयलाई हिलचेयरमैत्री बनाउन राष्ट्रिय भवन संहिता (NBC 206) को खण्ड ५ अनुरूपका मापदण्ड लागू

गर्नुपर्नेछ। साथै, दृष्टिविहीन सेवाग्राहीको सुविधाका लागि सहजै छान्न सकिने स्थानहरूमा भुइँबाट १.२ मिटर देखि १.६ मिटरको उचाइमा ब्रेल लिपिमा कार्यालय तथा कार्यकक्षहरूको नाम तथा स्पर्शमुखी मार्गनिर्देशक चिह्नहरू(Tactile Signage) राख्ने व्यवस्था मिलाउनुपर्नेछ।

१.४ कार्यरत कर्मचारी र सेवा लिन आउने सेवाग्राहीहरूका लागि पर्याप्त र छुट्टाछुट्टै सवारी बिसौनी (पार्किङ)को व्यवस्था हुन सक्ने स्थान छनोट गर्नुपर्नेछ। कार्यालयको सेवा प्रवाहको प्रकृतिलाई मध्यनजर गर्दै मालवाहक सवारीसाधन, चार पाङ्ग्रे, दुई पाङ्ग्रे र साइकलसमेत पार्किङ गर्न मिल्ने गरी आवश्यक स्थानको प्रबन्ध गर्नुपर्नेछ। पार्किङ सुविधा आवश्यकता र जग्गाको उपलब्धता अनुसार कार्यालय परिसरभित्र, बाहिर वा भवनको भूमिगत (Underground) तल्ला मा निर्माण गर्न सकिनेछ। साथै, व्यवस्थापन गरिने सबै पार्किङ स्थलहरू सुरक्षित र व्यवस्थित हुनु पर्नेछ।



चित्र २: कर्मचारी र सेवाग्राही सवारी बिसौनी को नमूना

१.५ सुरक्षित र बाढी/भूकम्प जोखिम न्यून क्षेत्र हुनुपर्नेछ ।

सरकारी कार्यालय भवन निर्माणका लागि भूकम्प, पहिरो र बाढीजस्ता प्राकृतिक प्रकोपको न्यूनतम जोखिम भएका सुरक्षित स्थानहरूलाई मात्र प्राथमिकता दिनुपर्नेछ। प्रचलित 'बस्ती विकास, सहरी योजना तथा भवन निर्माण सम्बन्धी आधारभूत निर्माण' सम्बन्धि मापदण्डका सुरक्षित स्थल छनोट सम्बन्धि व्यवस्था बमोजिमका स्थल छनोट गर्नुपर्नेछ ।

१.६ जग्गा विकास आयोजना भन्दा बाहिरका निर्माणयोग्य जग्गाहरू छनोट गर्दा, जग्गा विकास तथा साइट तयारीमा लाग्ने खर्चलाई विशेष ध्यान दिनुपर्नेछ। सरकारी स्रोतको मितव्ययी उपयोग सुनिश्चित गर्न, जग्गा सम्प्राप्ति वा विकास गर्ने, कम्पाउण्ड वाल लगाउने, पहुँच मार्ग निर्माण गर्ने आदि समेतको जम्मा खर्च प्रस्तावित भवन निर्माणको कुल लागतको बीस प्रतिशत भन्दा बढी हुनु हुँदैन। तर, विगतमा नै स्थापित कार्यालयको संरचना अपुग भई कार्यालय परिसर भित्र थप संरचना निर्माण गर्दा यो सीमा लागू हुने छैन ।

२. भवन संरचना

भवन संरचनाहरू डिजाइनदेखि नै प्रचलित भवन ऐन, नेपाल राष्ट्रिय भवन संहिता, भवन मापदण्ड लगायतका अनिवार्य मापदण्डहरूको पूर्ण पालना गरेर मात्र भवनको डिजाइन तथा निर्माण गर्नुपर्नेछ।

साथै, कार्यालय भवनको भित्री तथा बाहिरी संरचनाको डिजाइन गर्दा सेवाग्राही र कर्मचारीको स्वास्थ्य, सुरक्षा, सहजता र उत्पादकत्व अभिवृद्धिलाई प्राथमिकता दिनुपर्नेछ। स्वस्थ र आरामदायी कार्य-वातावरण सुनिश्चित गर्न उचित प्रकाश, हावा र ध्वनिको व्यवस्थापन हुने गरी झ्याल-ढोका तथा भवनको बाहिरी आवरण निर्माण गर्दा उपयुक्त प्रविधि र निर्माण सामग्रीको छनोट गर्नुपर्दछ। यसले स्थानीय समुदायको समग्र सौन्दर्य र परिवेशमा पार्ने प्रभावलाई विशेष ध्यान दिनुपर्दछ। भवन परिसर र भित्री कक्षबाट बाहिरी दृश्य कस्तो देखिने र वरपरका कुन पक्षलाई देखाउने वा नदेखाउने भन्ने कुराको पूर्व-आकलन डिजाइन प्रक्रियामै गरि निर्माण स्थल अनुसारको हुनुपर्छ। कार्य-सम्पादनमा तीव्रता र संरचनागत एकरूपता ल्याउन नमुना डिजाइन (Type Design) लाई प्राथमिकता दिइए तापनि निर्माण स्थल अनुसार भवनको दिशा, प्रवेश, निकास आदिमा आवश्यक परिमार्जन गर्नु पर्नेछ, भवनलाई स्थानीय परिवेशसँग जोड्न यसको बाहिरी आवरण तथा मुख्य देखिने भागमा स्थानीय मौलिक कला र वास्तुकलालाई प्रतिविम्बित गराउन प्राथमिकता दिनुपर्नेछ।

३. कार्यात्मक विन्यास

सार्वजनिक सेवा प्रवाहलाई द्रुत, सहज र प्रभावकारी बनाउन कार्यालयको कार्यात्मक विन्यास सेवाग्राही र कर्मचारी दुवैको अनुकूल हुनुपर्नेछ। कार्यालयको आन्तरिक विन्यास मुख्यतया सेवा प्रवाहको प्रभावकारिता, कर्मचारीको उत्पादकत्व, सुरक्षाको तहगत संवेदनशीलता र उपलब्ध स्रोतको उच्चतम उपयोग जस्ता आधारभूत सिद्धान्तमा आधारित हुनुपर्नेछ। यसका लागि मुख्य प्रवेशद्वारमै नागरिक वडापत्र र सोधपुछ काउन्टरहरू राख्न सकिनेछ। सम्पूर्ण सेवा एकै ठाउँमा (one stop solution) प्रदान गर्न सकिने गरी सेवाग्राहीको चाप, उमेर र शारीरिक क्षमतालाई दृष्टिगत गरी पर्याप्त क्षेत्रफलसहितको प्रतीक्षालय वा प्रतीक्षाकक्षको निर्माण हुनुपर्नेछ। सेवा प्रवाहलाई नागरिक मैत्री बनाउन प्रत्यक्ष जनसम्पर्क हुने सेवा कक्षहरू अनिवार्य रूपमा भुइँतलामा नै विन्यास गरी आन्तरिक कार्यक्षेत्रमा सर्वसाधारणको अनावश्यक आवतजावत मार्ग नियन्त्रण गरिनेछ।

यसैगरी, कार्यस्थल कामको प्रकृतिअनुसार व्यवस्थित हुनुपर्नेछ। कार्य-गोपनीयता, आपसी छलफल र औपचारिक वा अनौपचारिक बैठकका लागि छुट्टाछुट्टै कक्षहरूको विन्यास गरिनुपर्नेछ। पर्याप्त स्थान अभाव भएको अवस्थामा भने एउटै कक्षलाई आवश्यकताअनुसार बहुउद्देश्यीय रूपमा प्रयोग गर्न सकिने गरी लचिलो तथा पुनर्संरचनायोग्य डिजाइन अवलम्बन गर्नुपर्नेछ। भौतिक पहुँचका अवरोधहरू हटाई अपाङ्गता भएका व्यक्ति, ज्येष्ठ नागरिक र बालबालिकाका लागि समेत सहज पहुँच सुनिश्चित हुने गरी सर्वव्यापी समावेशी डिजाइनका आधारमा आन्तरिक पूर्वाधारको विन्यास हुनुपर्नेछ। समग्रमा, कार्यालयको डिजाइन पूर्ण रूपमा कार्यप्रवाह र सुरक्षा संवेदनशीलतामा आधारित हुनुपर्नेछ।

सरकारी कार्यालयहरूको भौतिक संरचना निर्माण तथा आन्तरिक विन्यास गर्दा बजेटको उच्चतम सदुपयोग, कार्यदक्षता र सेवा प्रवाहको प्रभावकारिता सुनिश्चित गर्न कार्यालयहरूको कार्यप्रकृति र सेवाग्राहीको चापका आधारमा देहायबमोजिम तिन समूहमा वर्गीकरण गरी सोही अनुरूपको वास्तुकला र स्थान विनियोजन गर्नुपर्नेछ:

क) समूह 'क': उच्च जनसम्पर्क र प्रत्यक्ष सेवा प्रवाह गर्ने कार्यालयहरू

यस समूह अन्तर्गत जिल्ला प्रशासन कार्यालय, राहदानी विभाग, राष्ट्रिय परिचयपत्र तथा पञ्जीकरण विभाग, कन्सुलर सेवा विभाग, मालपोत कार्यालय, नापी कार्यालय, यातायात व्यवस्था कार्यालय, वैदेशिक रोजगार विभाग, श्रम कार्यालय, आन्तरिक राजस्व कार्यालय तथा करदाता सेवा कार्यालय, भन्सार कार्यालय, विश्वविद्यालयका परीक्षा नियन्त्रण कार्यालयहरू जस्ता उच्च जनसम्पर्क र प्रत्यक्ष सेवा प्रवाह गर्ने कार्यालयहरू पर्नेछन्। यस्ता कार्यालयहरूको डिजाइन एकल बिन्दु सेवा केन्द्र (One Stop Service Center) को अवधारणा बाट गर्नुपर्दछ। सेवाग्राहीको प्रवाहलाई सम्भव भए सम्म एकतर्फी र रेखीय (प्रवेश →पालो(प्रतीक्षालय) →सेवा →बहिर्गमन) बनाई भीड व्यवस्थापन गर्ने गरी आन्तरिक विन्यास गर्नुपर्नेछ। भुइँतलामा अनिवार्य रूपमा खुला र पारदर्शी बृहत् एकल बिन्दु सेवा हल, पालो प्रणाली सहितको आवश्यकता अनुसारको फराकिलो र हावादार प्रतीक्षालय, पर्याप्त सार्वजनिक शौचालय र भीडभाड व्यवस्थापन गर्न आवश्यकता अनुसार फराकिलो करिडोर तथा अवरोधरहित निकासको व्यवस्था गर्नुपर्नेछ। साथै, सेवा प्रवाहलाई प्रविधि मैत्री बनाई छरितो सेवा दिन यस्ता कार्यालयमा स्वचालित टोकन प्रणाली, डिजिटल नागरिक बडापत्र, अडियो सुन्न सकिने बडापत्र, डिजिटल फारम भर्नाको लागि वाइफाई इन्टरनेट व्यवस्था आदिको समेत व्यवस्था गर्न सकिनेछ।

ख) समूह 'ख': प्राविधिक, वैज्ञानिक र विशिष्टीकृत कार्यालयहरू

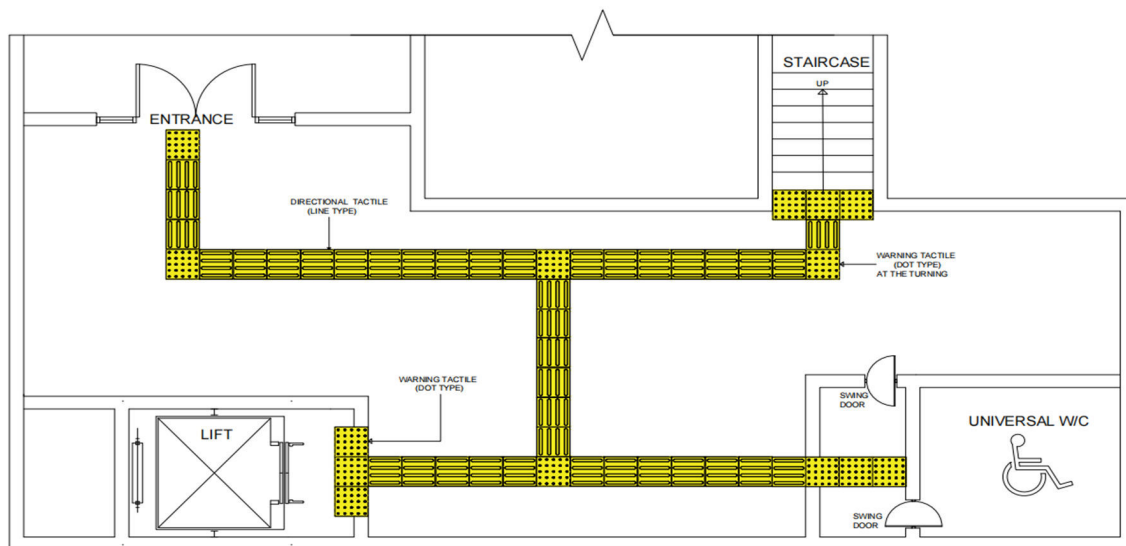
यस समूह अन्तर्गत पूर्वाधार विकास मन्त्रालय अन्तर्गतका विभिन्न विभाग मातहतका आयोजना तथा कार्यालयहरू, जलस्रोत तथा सिँचाई मातहतका आयोजना तथा कार्यालयहरू, प्रयोगशालाहरू (गुणस्तर, नापतौल, फोरेन्सिक आदि), सूचना प्रविधि तथा डाटा केन्द्र, कृषि तथा वन अनुसन्धान केन्द्रहरू, जल तथा मौसम विज्ञान कार्यालयहरू जस्ता प्राविधिक, वैज्ञानिक र विशिष्टीकृत कार्य गर्ने कार्यालयहरू पर्नेछन्। यस्ता कार्यालयहरूको विन्यास गर्दा प्रशासनिक कार्यको तुलनामा कामको प्राविधिक विशिष्टता, प्राविधिक उपकरणहरूको भौतिक सुरक्षा, सञ्चालन सहजता आदि लाई केन्द्रमा राखी सोही अनुरूपको सुरक्षित र वैज्ञानिक संरचना निर्माण गर्नुपर्नेछ। आवश्यकता अनुसार भारी उपकरण धान्न सक्ने भुइँ, आवश्यकता अनुसार वातानुकूलित र आवश्यकता अनुसार तथ्याङ्क केन्द्र वा सर्भर कक्ष, र अनुसन्धानकर्ताहरूका लागि ध्वनि नियन्त्रित शान्त कार्यकक्षहरूका साथै कार्य विशिष्टताका आधारमा थप कक्ष/ सुविधा को व्यवस्था गर्नुपर्नेछ।

ग) समूह 'ग': अन्य कार्यालयहरू

यस समूह अन्तर्गत मन्त्रालयहरू, विभागका केन्द्रीय कार्यालयहरू, निर्देशनालयहरू जस्ता सेवाग्राहीको प्रत्यक्ष भीडभाड कम हुने तर नीति निर्माण तथा प्रशासनिक कार्य गर्ने कार्यालयहरू पर्नेछन्। यस्ता कार्यालयहरूमा कर्मचारीहरूको उत्पादकत्व बढाउन भित्रि कार्यस्थल र खुला कार्यस्थल लाई प्राथमिकता दिई कार्य-गोपनीयता तथा आन्तरिक सुरक्षा सुदृढ हुने गरी कार्यालयको डिजाइन र आन्तरिक विन्यास गर्नुपर्नेछ। नीतिगत छलफलका लागि आधुनिक प्रविधिसहितका साना तथा ठूला बैठक र सम्मेलन कक्षहरू, विशिष्ट पाहुनाका लागि स्तरीय विशिष्ट अतिथि कक्ष, विशिष्ट पदाधिकारीका लागि सहायक कक्षसहितको कार्यकक्ष, र महत्त्वपूर्ण सरकारी दस्तावेजहरू सुरक्षित राख्न आगो तथा चिस्यान प्रतिरोधी सुरक्षित केन्द्रीय अभिलेखालयको व्यवस्था गर्नुपर्नेछ।

४. समावेशी पहुँच

सरकारी कार्यालयहरूले प्रवाह गर्ने सेवामा उमेर, लिङ्ग, शारीरिक वा मानसिक क्षमता तथा अवस्थाको पर्वाह नगरी सम्पूर्ण नागरिकको समान पहुँच सुनिश्चित गर्न, सबैले सुरक्षित र सम्मानपूर्वक प्रयोग गर्न सक्ने समावेशी भौतिक वातावरणको निर्माण गरिनुपर्नेछ। कार्यालय भवनको समग्र वास्तुकला विशेषगरी अपाङ्गता भएका व्यक्ति, ज्येष्ठ नागरिक, गर्भवती महिला, बालबालिका र अस्थायी शारीरिक समस्या भएका व्यक्तिहरूमैत्री हुनुपर्दछ। यसका लागि डिजाइन चरणदेखि नै 'पहुँचयुक्त भौतिक संरचना तथा



NOTE:

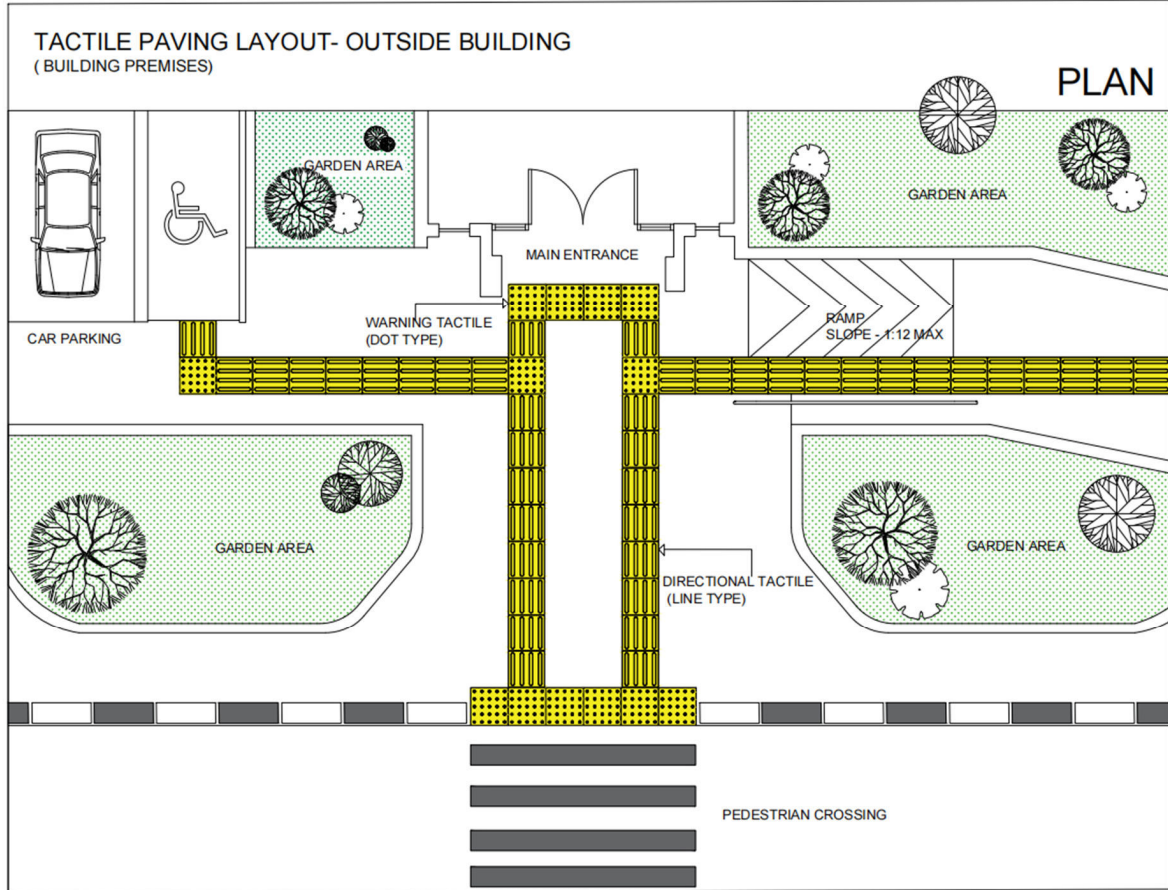
- DRAWING NOT TO SCALE
- ALL DIMENSIONS ARE IN MILLIMETRES
- PROVIDE TACTILE PAVING ON ACCESSIBLE ROUTE
- MAINTAIN 90 MM MIN. CLEAR WIDTH
- INSTALL AS PER ISO:23599-2012

चित्र ३: भवन भित्र प्रयोग हुने स्पर्शमुखी पदमार्ग (ट्याकटाईल पेभिङ)को नमुना

सञ्चार सेवा निर्देशिका, २०६९' र नेपाल राष्ट्रिय भवन संहिता (NBC 206) ले तोकेका मापदण्डहरूको पूर्ण रूपमा पालना गरिनुपर्नेछ ।

साथै, सरकारी कार्यालयलाई समावेशी, पहुँचयोग्य बनाउन देहायबमोजिम व्यवस्था गर्नु पर्नेछः

क) दृष्टिविहीन तथा न्यून दृष्टि भएका कर्मचारी वा सेवाग्राहीहरूलाई कार्यालयभित्र स्वतन्त्र र सुरक्षित रूपमा हिँडडुल गर्न सहज होस् भन्ने उद्देश्यले स्पर्शमुखी पदमार्ग(Tactile Walking Surface Indicators - TWSI) को आवश्यकता अनुसार व्यवस्था गर्नुपर्नेछ। सेतो छडी वा खुट्टाको स्पर्शबाट पहिचान गर्न सकिने यस प्रणालीले सेवाग्राहीलाई आत्मनिर्भरता प्रदान गर्दछ। यसका लागि कार्यालयको मुख्य मार्ग, गल्ली र सेवा कक्षहरूसम्म पुग्न दिशा देखाउने रेखायुक्त ढाँचा (Directional / Line type) को



चित्र ४: भवन बाहिर प्रयोग हुने ट्याकटाईल पेभिगको नमुना

आवश्यकता अनुसार प्रयोग गर्नुपर्नेछ। त्यसैगरी, दुर्घटनाबाट बचाउन तथा सतर्क गराउन सिँढी, लिफ्ट र सडक क्रसिङ जस्ता

स्थानहरूको अगाडि थोप्लायुक्त ढाँचा (Warning / Dot type) को ट्याक्टाइल बिछ्याउनुपर्नेछ।

1. WARNING /HAZARD INDICATOR
(DOT TYPE)

2. DIRECTIONAL INDICATOR
(LINE TYPE)

RECOMMENDED DIMENSIONS (ISO 23599:2012)		
1 .	ITEM	RECOMMENDED
2 .	TACTILE TILE SIZE	300 X 300 mm/ 600 X 600 mm
3 .	DOT (TOP DIA)	25-35 mm
4 .	DOT HEIGHT	4-5 mm
5 .	DOT SPACING (CENTER TO CENTER)	50-60 mm
6 .	STRIP WIDTH	25-25 mm
7 .	STRIP HEIGHT	4-5 mm
8 .	STRIP SPACING (CENTER TO CENTER)	45-75 mm
9 .	COLOR CONTRAST	>70 % CONTRAST RECOMMENDED
10 .	SURFACE	SLIP RESISTANT

COLOR CONTRAST EXAMPLE

CONTRAST > 70%

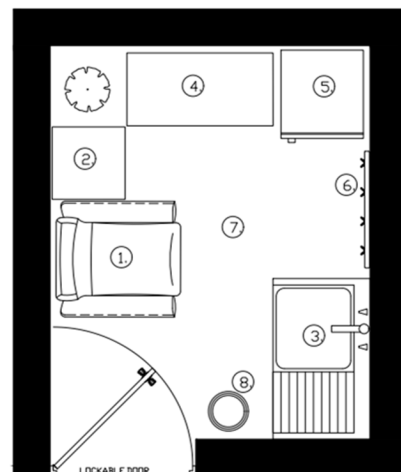
ख) विभिन्न शारीरिक तथा संवेदी (Sensory) कमजोरी भएका सेवाग्राहीहरूलाई लक्षित गरी कार्यालय भवन वा सार्वजनिक स्थानहरूमा बहु-संवेदी सङ्केत प्रणाली आवश्यकता अनुसार व्यवस्था गरिनुपर्नेछ। दृष्टि, श्रवण र स्पर्श जस्ता विभिन्न इन्द्रियहरूमार्फत जानकारी प्रदान गर्ने यस प्रणालीले विशेषगरी दृष्टिविहीन, श्रवणशक्ति कमजोर भएका तथा अन्य अपाङ्गता भएका व्यक्तिहरूलाई सुरक्षित र सहज रूपमा कार्यालयको वातावरण बुझ्न र सेवा लेनदेन गर्न मद्दत पुऱ्याउँछ। यस प्रणाली अन्तर्गत कार्यालय भवनमा मुख्यतया दुई व्यवस्था, एक; दृष्टिविहीन तथा न्यून दृष्टि भएका व्यक्तिहरूलाई आवाज मार्फत कार्यालयको स्थान, दिशा र सेवा प्रवाह हुने कक्षहरू सम्बन्धी जानकारी प्रदान गर्न श्रव्य नक्सा वा ध्वनिमय उद्घोष प्रणालीको आवश्यकता अनुसार व्यवस्था गर्नुपर्नेछ। दोस्रो, श्रवणशक्ति कमजोर वा नष्ट भएका सेवाग्राहीहरूलाई आपतकालीन अवस्थामा सतर्क गराउन वा पूर्वचेतावनी दिन उज्यालो वा चम्किने बत्ती (Flashing lights) सहितको दृश्यमूलक चेतावनी प्रणाली आवश्यकता अनुसार जडान गर्नुपर्नेछ।

ग) सरकारी कार्यालयहरूमा स्तनपान गराइरहेका आमाहरूका लागि आमा कक्षको आवश्यकता हुन सक्दछ, यसले कामकाजी आमालाई गोपनीयता, आराम, पहुँचयोग्यता सहज र सम्मानजनक वातावरण प्रदान गर्दछ। तसर्थ, ५० जनासम्म कर्मचारी संख्या भएका कार्यालयहरूमा कम्तीमा ५ वर्गमिटर क्षेत्रफल भएको आमाकक्ष र सो भन्दा बढी कर्मचारी संख्या कार्यालयहरूमा शिशु स्याहार कक्ष समेतको आवश्यकता अनुसार व्यवस्था गर्न सकिनेछ। यस्तो कक्ष अनिवार्य रूपमा भुइँतलामा, बाहिर निस्कन सहज हुने गरी, प्राकृतिक प्रकाश आउने र बालबालिकालाई चोट नलाग्ने नरम भुइँ तथा सुरक्षित घेराबार भएको हुनुपर्नेछ।

घ) ज्येष्ठ नागरिक तथा गर्भवती महिलाहरूलाई भीडभाडमा लामो समय प्रतीक्षा गर्नु नपर्ने गरी सुरक्षित र सम्मानजनक सेवा प्रदान गर्न विशेष प्राथमिक सेवा व्यवस्था लागू गर्नुपर्नेछ। यसका लागि पिउने पानी, पर्याप्त हावा-प्रकाश र आरामदायी कुर्सीसहितको छुट्टै प्रतीक्षालय निर्माण गर्नुका साथै तत्काल सेवा दिन छुट्टै प्राथमिकता काउन्टरको व्यवस्था मिलाउनुपर्नेछ।

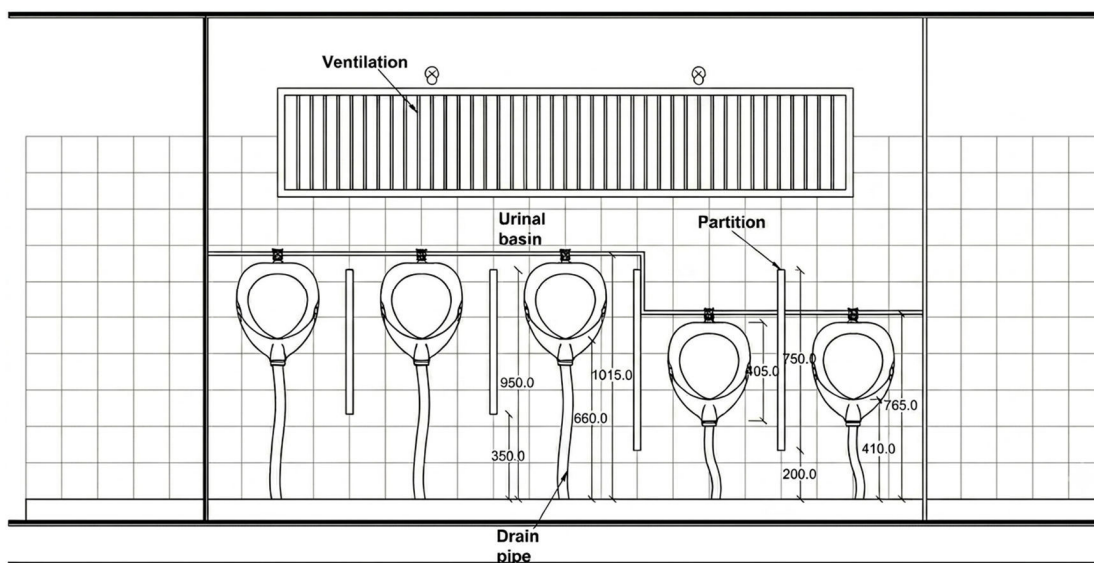
ड) कार्यालयमा सेवाग्राहीको रूपमा वा अन्य सेवाग्राही को साथमा बालबालिका समेत आगमन गर्न सक्ने बालबालिका समेत लाई ध्यानमा राखी डिजाइन गर्नु पर्नेछ।

। विशेष गरी कार्यालयको सोधपुछ कक्ष र शौचालय डिजाइन गर्दा विशेष ध्यान दिनु पर्नेछ।

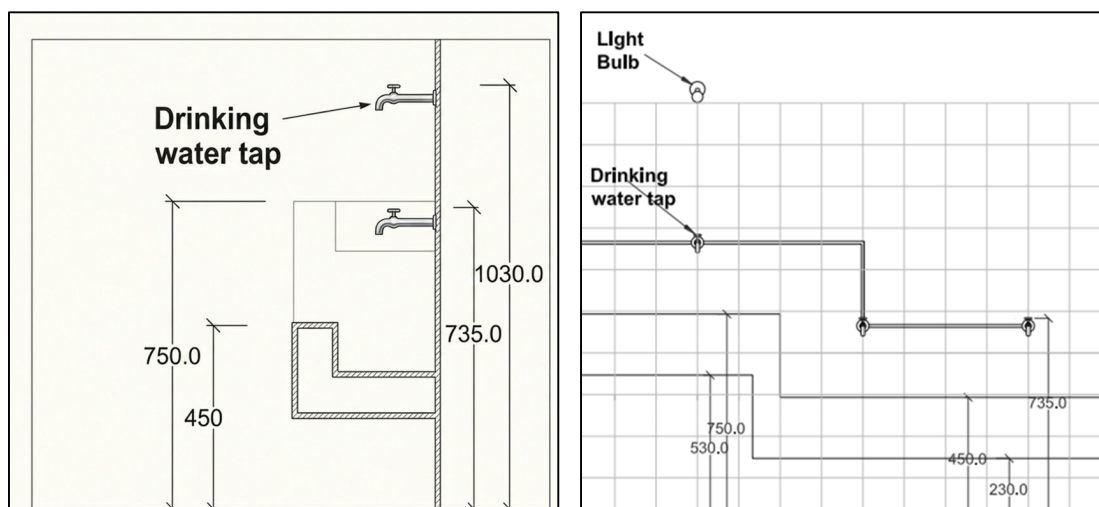


LEGEND	
1	COMFORTABLE CHAIR
2	SIDE TABLE WITH POWER OUTLET
3	SINK WITH RUNNING WATER
4	STORAGE CABINET/SHELVES
5	REFRIGERATOR (FOR MILK STORAGE)
6	COAT HOOKS
7	CLEAR CIRCULATION SPACE
8	TRASH BIN

चित्र ५: आमा कक्षको नमुना



चित्र ६: बालमैत्री पुरुष शौचालयको नमुना (फरक फरक उचाईका पिसाबदानी(युरिनल) देखाइएको)



चित्र ७: बालमैत्री शौचालयको नमुना (फरक फरक उचाईका धारा देखाइएको)

५. सूचना तथा प्रविधि पूर्वाधार

सरकारी कार्यालयमा सूचना तथा प्रविधि पूर्वाधारलाई अभिन्न अङ्गको रूपमा आवश्यकता अनुसार समावेश गर्नुपर्नेछ । सूचना तथा प्रविधिलाई प्रभावकारी बनाउन देहाय बमोजिम गर्नु पर्नेछ:

५.१ सरकारी कार्यालयहरूको कार्यसम्पादनलाई प्रविधिमैत्री र प्रभावकारी बनाउन भवन निर्माणको डिजाइन चरणमै सूचना तथा प्रविधि योजनालाई अभिन्न अङ्गको रूपमा समावेश गर्नुपर्नेछ। प्रत्येक सरकारी भवनको वास्तुकला (Architectural) तथा विद्युतीय (Electrical) डिजाइन तयार गर्दा आवश्यकता अनुसार सूचना तथा प्रविधि विन्यास डिजाइनसमेत तयार गरी विस्तृत परियोजना प्रतिवेदनमा समावेश गर्नुपर्नेछ। यसका साथै, भवन निर्माणको कार्य सुरु हुनुअगावै आवश्यकता अनुसार व्यवस्थित तार जडान प्रणाली, सर्भर रूम, सीसीटीभी, वाइफाइ कभरेज तथा पावर ब्याकअपको योजना तयार गर्नु पर्नेछ।

५.२ भवनभित्र खुला तार को प्रयोगलाई निषेध गर्दै सबै सरकारी भवनहरूमा न्यूनतम Cat-6 वा Cat-6A स्तरको व्यवस्थित तार जडान प्रणालीको प्रयोग गर्नुपर्नेछ। भवन निर्माणकै चरणमा तार बिछ्याउने मार्ग (Cable Tray) तथा पाइप (Conduit) को व्यवस्था मिलाई मुख्य सञ्जाल (Backbone Network) का लागि फाइबर अप्टिक केबलको प्रयोग गर्नुपर्नेछ। प्रत्येक कार्यकक्ष वा डेस्कमा न्यूनतम दुईवटा डाटा पोर्ट र एउटा भ्वाइस पोर्टका साथै आवश्यकता अनुरूप वाइफाइ एक्सेस पोइन्टको प्रावधान राख्नुपर्नेछ। भविष्यमा हुन सक्ने पूर्वाधार विस्तारलाई मध्यनजर गर्दै केबलिङ र नेटवर्क प्रणालीमा कम्तीमा तीस प्रतिशत अतिरिक्त क्षमता (Spare Capacity) सुनिश्चित गर्नुपर्नेछ।

५.३ कार्यालयको आवश्यकता अनुसार कम्तीमा एउटा स्तरीय सर्भर कोठा निर्माण गर्नुपर्नेछ, जसलाई कुनै पनि अवस्थामा भूमिगत तलामा राख्न निषेध गरिएको छ । सर्भर रूममा चौबिसै घण्टा अठारदेखि चौबिस डिग्री सेल्सियस तापक्रम कायम रहने विशिष्टकृत तापक्रम नियन्त्रण प्रणाली (Dedicated Temperature Control System), स्वचालित अग्नि नियन्त्रण प्रणाली, पहुँच नियन्त्रण, ब्याकअप र सीसीटीभी निगरानीको व्यवस्था हुनुपर्नेछ। सर्भर र्याक तथा प्याच प्यानलको विन्यास तोकिएको मापदण्ड अनुरूप

हुनुपर्नेछ भने संवेदनशील डाटा रहने कार्यालयहरूमा छुट्टै मिनी तथ्याङ्क केन्द्र स्थापना गर्नुपर्नेछ। सर्भर रूममा स्थिर विद्युत-रोधी (Anti-static) तथा उचालिएको भुइँको व्यवस्थाका साथै उपकरणहरूको उचित अर्थिङ गरिनुपर्नेछ र यसका सुरक्षित कोठा, अग्नि-प्रतिरोधी पर्खाल र ढोकाहरू राष्ट्रिय भवन संहिता (NBC 107) अनुरूप निर्माण गर्नुपर्नेछ।

५.४ सुरक्षित तथा भरपर्दो सञ्चारका लागि सरकारी कार्यालयहरूमा आवश्यकता अनुसार उच्च गतिको फाइबर इन्टरनेट र सेवामा अवरोध नआओस् भन्नका लागि कम्तीमा दुईवटा फरक सेवा प्रदायक (ISP) सहितको वैकल्पिक तथा निरन्तर सञ्जाल (Redundant Network) प्रणाली आवश्यकता अनुसार राख्नुपर्नेछ। कोर स्विच र म्यानेज्ड नेटवर्क प्रणालीको प्रयोग गर्दै कार्यालयको आन्तरिक नेटवर्क र अतिथिका लागि प्रयोग हुने नेटवर्क (Guest Wi-Fi) लाई भर्चुअल लोकल एरिया नेटवर्क (VLAN) मार्फत छुट्टाछुट्टै व्यवस्था गरी केन्द्रीकृत वाइफाइ व्यवस्थापन प्रणाली लागू गर्न सकिनेछ। साथै, म्यानेज्ड स्विच, राउटर र फायरवालको ग्राउन्डिङ व्यवस्था राष्ट्रिय भवन संहिता (NBC 207) अनुसार हुनुपर्नेछ।

५.५ बलियो साइबर सुरक्षा पूर्वाधारलाई न्यूनतम आवश्यकताको रूपमा स्थापित गर्न नेटवर्क सुरक्षा प्रणाली संस्थागत फायरवाल जडानका साथै सम्पूर्ण उपकरणहरूमा एन्टिभाइरस तथा एन्डपोइन्ट संरक्षण प्रणाली राख्नुपर्नेछ। प्रणालीमा अनधिकृत पहुँच रोक्न बहु-चरणीय प्रमाणीकरण प्रणाली लागू गर्नुपर्नेछ भने डाटा भण्डारणका लागि सरकारी क्लाउड वा सरकारबाट स्वीकृत तथ्याङ्क केन्द्र भएमा सो को मात्र प्रयोग गरी नियमित डाटा ब्याकअप, प्रतिकृति र विपद् पुनःबहाली प्रणालीसमेत स्थापना गर्नुपर्नेछ।

५.६ विद्युतीय सुरक्षा र निरन्तरतालाई ध्यानमा राख्दै सूचना तथा सञ्चार प्रणालीका लागि छुट्टै विद्युतीय परिपथ (Dedicated Electrical Circuit) को व्यवस्था गर्नुपर्नेछ। विद्युत् आपूर्तिको लागि दुई देखि चार घण्टासम्म ब्याकअप दिन सक्ने अनलाइन यूपीएस प्रणालीको प्रयोग गर्दै यसलाई जेनेरेटर ब्याकअपसँग आवश्यकता अनुसार जोड्नुपर्नेछ। भोल्टेजको उतारचढावबाट उपकरण बचाउन विद्युतीय उतारचढाव नियन्त्रक र उचित अर्थिङको व्यवस्था मिलाउनुपर्नेछ।

५.७ सरकारी कार्यालयहरूलाई क्रमशः आधुनिक तथा प्रविधिमैत्री (स्मार्ट) कार्यालयमा रूपान्तरण गर्न आवश्यकता अनुसार विभिन्न प्रविधिहरू लागू गर्नुपर्नेछ। यस अन्तर्गत भिडियो कन्फ्रेन्सिङ हल, स्मार्ट प्रदर्शन यन्त्र (डिस्प्ले) सहितको मिश्रित(हाइब्रिड) बैठक कक्ष, विद्युतीय हाजिरी तथा बायोमेट्रिक पहुँच प्रणाली, र कागजरहित प्रशासनका लागि ई-फाइल तथा कागजात व्यवस्थापन प्रणाली वा सो सरहको प्रणालीको प्रयोग गर्नुपर्नेछ। साथै, सेवाम्राहीको चाप हुने कार्यालयहरूमा One stop solution को परिकल्पनालाई साकार पार्न अतिथि व्यवस्थापन, लाइन वा भीडभाड व्यवस्थापन, सार्वजनिक उद्घोषण प्रणाली र फाइल निगरानी (ट्र्याकिङ) प्रणालीको समेत व्यवस्था गर्नुपर्नेछ।

५.८ सुरक्षा संवेदनशीलतालाई दृष्टिगत गरी सरकारी कार्यालयहरूमा एकीकृत सुरक्षा प्रणाली लागू गर्नुपर्नेछ। सम्पूर्ण भवन परिसरमा आईपी (IP) आधारित सीसीटीभी जडान गर्नुपर्नेछ, जसको रेकर्डिङ क्षमता कम्तीमा ३० दिनको हुनुपर्नेछ। विशेषगरी मुख्य प्रवेशद्वार, सर्भर रूम र सार्वजनिक सेवा प्रवाह हुने क्षेत्रहरूमा सीसीटीभी निगरानी को व्यवस्था गर्नुपर्नेछ।

५.९ भवनको अग्नि नियन्त्रण प्रणाली लाई सूचना तथा सञ्चार प्रणालीसँग समन्वय र एकीकृत गर्नुपर्नेछ। यसका लागि सङ्केतमुखी अग्नि पूर्वचेतावनी प्रणाली (Addressable Fire Alarm) र सर्भर कक्षमा अग्नि नियन्त्रण प्रणाली (Fire Suppression

System)को प्रयोग आवश्यकता अनुसार गर्नु पर्नेछ। आपत्कालीन अलार्मलाई सेवाग्राही उद्घोषण(पब्लिक एड्रेसिड)प्रणाली सँग जोड्नुपर्नेछ भने वातानुकूलन (HVAC) प्रणाली र फायर ड्याम्पर प्रणालीलाई फायर अलार्मसँग इन्टरलक गर्नुपर्नेछ। साथै, सम्पूर्ण अग्नि नियन्त्रण तथा विद्युतीय उपकरणहरूको जडान राष्ट्रिय भवन संहिता (NBC 207) को पूर्ण रूपमा पालना हुने गरी गर्नुपर्नेछ।

६. स्वास्थ्य तथा सरसफाइ

६.१ कार्यालय परिसरमा कर्मचारी र सेवाग्राहीको चाप/संख्यालाई मध्यनजर गर्दै महिला, पुरुष र अपाङ्गता भएका व्यक्तिहरूका लागि सहज पहुँचयुक्त, पर्याप्त र सफा शौचालयको व्यवस्था गर्नुपर्नेछ। शौचालयको डिजाइन तथा निर्माण नेपाल राष्ट्रिय भवन संहिता (NBC 206 र NBC 208) को मापदण्ड बमोजिम हुनुपर्नेछ।

६.२ कार्यालय भवनको डिजाइन गर्दा प्रतिव्यक्ति प्रतिदिन न्यूनतम पैंतालीस लिटर पानीको आवश्यकता पर्ने अनुमानका आधारमा पानीको आपूर्ति प्रणाली तय गर्नुपर्नेछ। कार्यालयमा सबैको सहज पहुँच हुने गरी प्रत्येक तलामा पराबैंगनी र रिभर्स ओसमोसिस (UV तथा RO) प्रविधि जडित पिउने शुद्ध पानी उपलब्ध गराउने मेसिन व्यवस्था गर्नुपर्नेछ। उपलब्ध गराइने पिउने पानीको गुणस्तर अनिवार्य रूपमा नेपाल सरकारको राष्ट्रिय खानेपानी गुणस्तर मापदण्ड अनुकूल हुनुपर्नेछ।

६.३ कार्यालय परिसरमा नियमित सरसफाइ र फोहोरको वैज्ञानिक व्यवस्थापन प्रणाली अनिवार्य रूपमा अवलम्बन गर्नुपर्नेछ। फोहोरलाई स्रोतमै वर्गीकरण गर्न सजिलो हुने गरी देहाय बमोजिमका रङ्गका डस्टबिनहरूको व्यवस्था गर्नुपर्नेछ:

- हरियो: कुहिने फोहोरका लागि।
- निलो: नकुहिने तर पुनः प्रशोधन/प्रयोग गर्न सकिने (प्लास्टिक, कागज आदि)फोहोरका लागि।
- रातो: जोखिमपूर्ण तथा खतरनाक फोहोरका लागि।

६.४. बिग्रीएका विद्युतीय उपकरण, ब्याट्री र तारहरूको सुरक्षित भण्डारण तथा व्यवस्थापनका लागि कार्यालय परिसरमा छुट्टै विद्युतीय फोहोर सङ्कलन कक्षको व्यवस्था गर्न सकिनेछ।

६.५ प्रयोगकर्ताको संख्या र आवश्यकतालाई दृष्टिगत गरी महिला शौचालयमा सेनेटरी प्याड उपलब्ध गराउने मेसिनको व्यवस्था गर्नुपर्नेछ। साथै, प्रयोग गरिएका प्याडहरूको सुरक्षित विसर्जनका लागि महिला शौचालयभित्रै भस्मीकरण यन्त्र (Incinerator) वा अन्य उपयुक्त प्रविधि आवश्यकता अनुसार जडान गर्नुपर्नेछ।

६.६ फोहोर पानी व्यवस्थापनका लागि भवनको क्षमता अनुसार फोहोर ढल ट्याङ्की (सेप्टिक ट्याङ्क), सोसकुवा (सोक पिट) वा ढल प्रशोधन प्रणालीको निर्माण नेपाल राष्ट्रिय भवन संहिता (NBC 208) तथा प्रचलित स्थानीय मापदण्ड बमोजिम गर्नुपर्नेछ। ढल निकास प्रणाली र आकासे पानी निकास प्रणालीलाई अनिवार्य रूपमा छुट्टाछुट्टै व्यवस्था गर्नुपर्नेछ।

७. सुरक्षा व्यवस्था

सरकारी कार्यालय र यसका परिसरहरूलाई विभिन्न प्राकृतिक तथा मानव सिर्जित प्रकोपबाट सुरक्षित राख्न देहाय बमोजिमका सुरक्षा मापदण्डहरू पालना गर्नुपर्नेछ:

७.१ सरकारी कार्यालयको परिसर तथा भवनहरूमा नेपाल राष्ट्रिय भवन संहिता (NBC 107 र NBC 206) को पूर्ण पालना गर्दै उपयुक्त अग्नि प्रतिरोध तथा नियन्त्रण प्रणाली जडान गर्नुपर्नेछ। भवनमा फायर अलार्म, धुवाँ सूचक यन्त्र, अग्नि नियन्त्रक पाइप प्रणाली र हाते अग्नि नियन्त्रक यन्त्र को व्यवस्था देहायका बमोजिम सुनिश्चित हुनुपर्नेछ:

क) भवनको प्रत्येक तलामा प्रति २०० वर्गमिटर क्षेत्रफल बराबर १ वटा वा अधिकतम १५ देखि २० मिटरको पैदल दूरीमा भेटिने गरी पोर्टेबल फायर एक्स्टिङ्गुइसर राख्नुपर्नेछ। सामान्य कार्यालय क्षेत्रका लागि न्यूनतम ४.५ किलोग्राम क्षमताको ए.बी.सी. प्रकारको(ABC Type) र विद्युतीय कक्ष तथा सर्भर कक्षमा लघु परिपथ (सर्ट सर्किट)बाट हुने आगलागी नियन्त्रण गर्न न्यूनतम ४.५ किलोग्राम क्षमताको कार्बन डाइअक्साइड अग्नि नियन्त्रक (एक्स्टिङ्गुइसर) वा क्लिन एजेन्ट ग्याँस प्रणाली प्रयोग गर्नुपर्नेछ।

ख) १५ मिटरभन्दा अग्ला वा ठूला सार्वजनिक तथा सरकारी भवनहरूमा आन्तरिक फायर हाइड्रान्ट प्रणालीको व्यवस्था अनिवार्य हुनेछ। प्रत्येक हाइड्रान्ट स्टेसनले ९२६ देखि १००० वर्ग मिटर क्षेत्रफल समेट्ने गरी आपत्कालीन भन्ड्याड वा अग्नि सुरक्षित कक्ष को नजिक सहज पहुँच हुने स्थानमा जडान गर्नुपर्नेछ। प्रत्येक हाइड्रान्ट आउटलेटमा न्यूनतम ३ देखि ३.५ किलोग्राम प्रति वर्ग सेन्टिमिटर (३०-३५ मिटर हेड) को निरन्तर चाप (Residual Pressure) कायम हुनुपर्नेछ। भवनको छत मा एयर भल्भ र परीक्षण भल्भ हुनुपर्नेछ। त्यस्तै; प्रत्येक हाइड्रान्ट स्टेसनमा न्यूनतम २० मि.मि. व्यास र ३० देखि ३६ मिटर लम्बाइ भएको रबर होज तथा ६३ मि.मि. को ल्यान्डिङ भल्भ, ६३ मि.मि. व्यास भएका १५ मिटर लम्बाइका दुईवटा 'Reinforced Rubber Lined' पाइप, आवश्यक कपलिङ र १२ मि.मि. नोजल भएको ब्रान्च पाइप जस्ता उपकरण हुनुपर्नेछ।

ग) प्रणालीमा मुख्य विद्युतीय पम्प, स्ट्यान्डबाइ पम्प (डिजेल इन्जिन वा जेनेरेटरबाट चल्ने) र जकी पम्प जडान गर्नुपर्नेछ। प्रणालीमा पानीको चाप घट्दा पम्प स्वचालित हुने हुनुपर्नेछ। फायर पम्प कक्षलाई न्यूनतम २ घण्टासम्म आगो प्रतिरोध गर्न सक्ने संरचनाभित्र सुरक्षित गर्नुपर्नेछ। अग्नि नियन्त्रणको प्रयोजनका लागि मात्र NBC 208 मा तोकिएको क्षमताको छुट्टै पानी ट्याङ्की को व्यवस्था गर्नुपर्नेछ। ठूला भवनहरूको हकमा जोखिम मूल्याङ्कनका आधारमा क्षमता वृद्धि गर्नुपर्नेछ। यो ट्याङ्की दैनिक प्रयोग हुने खानेपानी आपूर्ति प्रणालीबाट भौतिक रूपमा पूर्णतः अलग हुनुपर्नेछ।

घ) अग्नि नियन्त्रक उपकरणहरूको प्रत्येक महिना नियमित निरीक्षण र उत्पादकको सिफारिस अनुसार पुनः भरण तथा जलस्थिर परीक्षण (हाइड्रो-टेस्टिङ) गराउनुपर्नेछ। यसको सम्पूर्ण अद्यावधिक विवरण मर्मतसम्भार लगबुकमा अनिवार्य रूपमा प्रविष्ट गर्नुपर्नेछ।

यसका साथै, कार्यालयमा कार्यरत कर्मचारीहरूको सहभागितामा प्रत्येक छ महिनामा कम्तीमा एक एक पटक अग्नि सुरक्षा अभ्यास अनिवार्य रूपमा सञ्चालन गर्नुपर्नेछ।

७.२ विपद्को समयमा सुरक्षित निकासका लागि व्यवस्थित आपत्कालीन निकास योजना तयार गरी भवनका मुख्य गल्ली तथा कोरिडोरहरूमा स्पष्ट रूपमा टाँस्नु पर्नेछ। आपत्कालीन निकासका लागि निकास(exit) चिह्नहरू अँध्यारोमा पनि चम्किने र स्पष्ट देखिने गरी राख्नुपर्नेछ। भवनका मुख्य कोरिडोरहरूमा "तपाईं अहिले यहाँ हुनुहुन्छ" भन्ने सङ्केत र बाहिर निस्कने दिशा देखाउने नक्सा टाँसिएको हुनुपर्नेछ। आपत्कालीन ढोकाहरू सधैं बाहिरतिर खुल्ने हुनुपर्नेछ र तिनलाई कहिल्यै पनि ताल्चा लगाएर बन्द गरिनु हुँदैन। यस्ता आपत्कालीन ढोकाहरूमा भित्रबाट हल्का धकेल्ने बित्तिकै सहजै खुल्ने आपत्कालीन चुकुल अनिवार्य रूपमा जडान गरिएको हुनुपर्नेछ।

७.३ कार्यालय परिसरको भौतिक सुरक्षा, अनुचित प्रवेश नियन्त्रण र निगरानी प्रणालीका लागि आवश्यकता अनुसार सुरक्षा गार्ड र गार्ड चौकीको उचित व्यवस्था मिलाउनुपर्नेछ। सुरक्षा गार्ड तथा निगरानी प्रणालीलाई थप प्रभावकारी बनाउन सीसीटीभी जस्ता जाँच प्रणालीसँग आबद्ध गर्नुपर्नेछ।

७.४ भूकम्प, आगलागी वा अन्य कुनै पनि विपद्को समयमा भवनभित्र रहेका सम्पूर्ण व्यक्तिहरू सुरक्षित रूपमा जम्मा हुन सक्ने गरी भवन बाहिर खुला र सुरक्षित क्षेत्रको अनिवार्य रूपमा व्यवस्था गरी स्पष्ट रूपमा सङ्केत चिह्न राखिएको हुनुपर्नेछ।

७.५ भवनको संरचनात्मक सुरक्षा सुनिश्चित गर्न निर्माण स्थलको माटोको भारवहन क्षमताको आवश्यकता अनुसार विस्तृत परीक्षण गरी सो को आधारमा सुरक्षित र विपद् प्रतिरोधी भवन संरचना निर्माण गर्नुपर्नेछ।

८. वातावरणीय दिगोपन

सरकारी कार्यालयका भवनहरूलाई पर्यावरणमैत्री, ऊर्जा मितव्ययी र दिगो बनाउन निर्माणदेखि सञ्चालन अवधिसम्म देहायबमोजिमका मापदण्डहरू पालना गर्न अनुसूची २ मा उल्लिखित हरित भवन मार्गदर्शन (Green building Guidelines) अनुसार गर्नुपर्नेछ:

क) भवनको डिजाइन स्थानीय हावापानी र जलवायु अनुकूल हुनुपर्नेछ। सूर्यको दिशा र हावाको बहावलाई ध्यानमा राखी प्राकृतिक प्रकाश र हावाको प्रवाह को अधिकतम उपयोग हुने डिजाइन गर्नुपर्नेछ। कम ऊर्जा खपतमा पनि भवनभित्र उपयुक्त तापक्रम कायम राख्न गारो, छाना, ढोका र झ्यालहरू निर्माण गर्दा इन्सुलेसन सहितका ऊर्जा दक्ष प्रविधि र सामग्रीको प्रयोग आवश्यकता अनुसार गर्नुपर्नेछ।

ख) कार्यालयका बत्ती, कम्प्युटर, सर्भर र अन्य विद्युतीय उपकरणहरूलाई निरन्तर सञ्चालन गर्न भवनको छत वा खुला स्थानमा सौर्य ऊर्जा प्रणाली आवश्यकता अनुसार जडान गरी स्वच्छ तथा नवीकरणीय ऊर्जाको भरपर्दो व्यवस्था गर्नुपर्नेछ।

ग) निर्माण सामग्री छनोट गर्दा भवनको सम्पूर्ण आयुभरिको सञ्चालन तथा मर्मत खर्च न्यून हुने गरी टिकाउ र दिगो सामग्रीको छनोट गर्नुपर्नेछ। वातावरणमा पर्ने असर न्यूनीकरण गर्न स्थानीय स्तरमा उपलब्ध, पुनः प्रयोग गर्न मिल्ने, र न्यून कम कार्बन उत्सर्जन भएका

निर्माण सामग्रीलाई प्राथमिकता दिनुपर्नेछ। मानव स्वास्थ्य र वातावरणमा असर पर्ने हानिकारक रसायनको प्रयोग न्यूनीकरण गर्दै न्यून रासायनिक उत्सर्जन भएका रङ, टाँस्ने पदार्थ र फर्निचरको प्रयोगलाई प्राथमिकता दिनुपर्नेछ।

घ) कार्यालयको छाना तथा खुला क्षेत्रमा परेको आकाशे पानी संकलन गर्न रेनवाटर हार्भेस्टिङ प्रणाली जडान गर्नुपर्नेछ। यसरी संकलित पानीलाई ट्याङ्कीमा भण्डारण गरी शौचालय फ्लस गर्न र बगैँचामा सिँचाइ गर्न प्रयोग गर्ने वा जमिनमुनिको पानी पुनर्भरण गराउने व्यवस्था गर्नुपर्नेछ।

ड) निर्माण सामग्री छनोटदेखि भवन सञ्चालनमा आइसकेपछिको अवस्थासम्म कार्बन उत्सर्जन, ध्वनि र धुलो प्रदूषण न्यूनतम हुने नीति अपनाउनुपर्नेछ। पानीको कम खपत, फोहोरको न्यूनीकरण र वातावरणीय संरक्षणका लागि हरित भवनका अनुसूची-२ का व्यवस्थालाई भवनको डिजाइनमै पूर्ण रूपमा समावेश गर्नुपर्नेछ।

९. स्तरीकृत डिजाइन

देशभरका सरकारी कार्यालयहरूमा एकरूपता कायम गर्न, संस्थागत पहिचान झल्काउन र सेवाग्राहीलाई जुनसुकै कार्यालयमा जाँदा पनि परिचित अनुभूति प्रदान गर्न भौतिक पूर्वाधार र आन्तरिक विन्यासमा देहाय बमोजिम गर्नुपर्नेछ:

क) समान तह र जिम्मेवारी भएका पदाधिकारी तथा कर्मचारीहरूको कार्यक्षेत्र क्षेत्रफल देशभरका सबै सरकारी कार्यालयमा एकरूप हुने गरी अनुसूची १ मा भएका व्यवस्था अनुरूप मात्र निर्माण वा व्यवस्थापन गर्नुपर्नेछ।

ख) सबै नागरिकलाई सहज रूपमा सेवा प्रवाह गर्न एकल बिन्दु सेवा डेस्क र स्वागत डेस्कको मुख्य भागको अधिकतम उचाइ १०० मि.मी. कायम गर्नुपर्नेछ। साथै, बालबालिका, हिलचेयर प्रयोगकर्ता सेवाग्राही र होचा कद भएका प्रयोगकर्ता सेवाग्राहीलाई समेत सहज हुने गरी डेस्कको बाँकी भागको उचाइ अधिकतम ७५० मि.मी. कायम गर्नुपर्नेछ।

ग) सेवाग्राही प्रतीक्षालयको सिट डिजाइन, नागरिक बडापत्र, र सूचना पाटीहरू नेपाल सरकारले तोकेको निश्चित र साझा ढाँचा मा मात्र निर्माण तथा जडान गर्नुपर्नेछ। मार्गनिर्देशन गर्ने सङ्केतहरू अनुसूची ३ को व्यवस्था अनुसार गर्नुपर्नेछ।

घ) कार्यालय भवनको भित्री तथा बाहिरी आवरणमा प्रयोग हुने रङहरू अनिवार्य रूपमा 'सार्वजनिक भवनहरूमा प्रयोग हुने रङसम्बन्धी निर्देशिका, २०६९' बमोजिम हुनुपर्नेछ। साथै, सरकारी लोगो र संस्थागत सङ्केत प्रणालीहरू तोकिएको मापदण्ड अनुरूप देशभर एकरूपता कायम गर्नुपर्नेछ।

१०. सहकार्य र उत्पादकत्वको कार्यसंस्कृति प्रवर्द्धन

सरकारी कार्यालयहरूमा परम्परागत, एकान्तमुखी र सुस्त कार्यशैलीलाई विस्थापित गर्दै आधुनिक, गतिशील र परिणाममुखी कार्यवातावरण निर्माण गर्नुपर्नेछ। भौतिक पूर्वाधार तथा आन्तरिक विन्यासले कर्मचारीको मनोविज्ञान र कार्यक्षमतामा प्रत्यक्ष प्रभाव पार्ने हुँदा, कर्मचारीहरूको शारीरिक तथा मानसिक स्वास्थ्य, सन्तुष्टि र आपसी समन्वय अभिवृद्धि गर्न कार्यालयको समग्र कार्य-वातावरणलाई देहायबमोजिम व्यवस्थित गर्नुपर्नेछ:

१०.१ कर्मचारीहरूको श्वासप्रश्वास सम्बन्धी स्वास्थ्य अवस्थालाई सुरक्षित राख्न र कार्यक्षमता अभिवृद्धि गर्न कार्यालय भवनभित्र शुद्ध हावाको निरन्तर प्रवाह र तापक्रमको वैज्ञानिक व्यवस्थापन देहायबमोजिम गर्नुपर्नेछ:

क) कार्यालयभित्र पर्याप्त अक्सिजनको मात्रा कायम राख्न र हावा गुमिन नदिन कार्बन-डाइअक्साइडको स्तर अधिकतम एक हजार पीपीएम भन्दा बढी हुन नदिने सुनिश्चित गर्नुपर्नेछ।

ख) कर्मचारीको शारीरिक सहजताका लागि कार्यकक्षको तापक्रम सामान्यतया बाईस डिग्री सेल्सियस देखि छब्बीस डिग्री सेल्सियस भित्र र सापेक्षिक आर्द्रता चालीस प्रतिशत देखि साठी प्रतिशतको बीचमा निरन्तर कायम हुने व्यवस्था गर्नुपर्नेछ।

ग) कार्यालय भवनमा HVAC जडान गर्दा भित्रकै पुरानो हावा मात्र घुमाउने प्रविधिको सट्टा बाहिरको शुद्ध हावा भित्र तान्ने प्रणाली आवश्यकता अनुसार जडान गर्नुपर्नेछ।

घ) सम्भव भएसम्म कृत्रिम प्रणालीमाथिको निर्भरता कम गर्न प्राकृतिक हावाको प्रवाह सहज रूपमा हुने गरी झ्याल तथा भेन्टिलेटरहरूको उपयुक्त डिजाइन र व्यवस्था गर्नुपर्नेछ।

ड) शौचालय, खाजाघर, छपाइ कक्ष र सर्भर कक्ष जस्ता विशेष स्थानहरूमा प्राकृतिक भेन्टिलेसनको अभाव भएमा वा दुर्गन्ध, हानिकारक ग्यास र तातो हावा उत्पन्न हुने अवस्थामा त्यसलाई तत्काल बाहिर फाल्न छुट्टै दूषित हावा बाहिर फाल्ने (Exhaust Ventilation) प्रणाली जडान गर्नु पर्नेछ ।

१०.२ कार्यालयको कार्य-वातावरणलाई शान्त, बाधा रहित र आँखाका लागि अनुकूल बनाउन ध्वनि र प्रकाशको वैज्ञानिक व्यवस्थापन देहायबमोजिम गर्नुपर्नेछ:

क) सामान्य कार्यक्षेत्रभित्रको ध्वनि स्तर (Noise Level) अधिकतम ४० देखि ४५ डेसिबल (40–45 dB) भित्र सीमित राख्ने व्यवस्था गर्नुपर्नेछ। कार्यालय बाहिरको हो-हल्लाले काममा बाधा नपरोस् भन्नका लागि भवनको बाहिरी आवरण तथा झ्यालहरूमा आवश्यकताअनुसार दोहोरो सिसायुक्त झ्याल (Double-glazed window) वा ध्वनिरोधी सिसाको प्रयोग गर्नुपर्नेछ। बैठक कक्ष र गोप्य कार्यकक्षहरूमा ध्वनि बाहिरिन वा भित्रिन नदिन ध्वनि रोक्ने प्रविधि सहितको पार्टिसन वा भित्ता प्यानल को प्रयोग गर्न सकिनेछ । त्यस्तै, सम्भव भएसम्म जेनेरेटर, HVAC, प्रिन्टर जस्ता ध्वनि उत्पादन गर्ने मेसिनहरूलाई मुख्य कार्यक्षेत्रभन्दा छुट्टै सुविधा क्षेत्र (सर्भिस जोन) मा राख्नुपर्नेछ। साथै, आवाज गुन्जिने समस्या कम गर्न सिलिङ र भित्ताहरूमा आवाज सोस्ने सामग्रीको प्रयोग गर्न सकिने छ ।

ख) कार्यालयको सामान्य कार्यक्षेत्रमा आँखामा पर्ने तनाव (Eye strain) र दृष्टिभ्रम कम गर्न प्रकाशको स्तर ३०० देखि ५०० लक्स (300–500 Lux) कायम गर्नुपर्नेछ। सम्भव भएसम्म कृत्रिम बत्तीको प्रयोग कम गर्ने र प्राकृतिक प्रकाशको अधिकतम उपयोग हुने गरी वर्कस्टेसनको विन्यास डिजाइन गर्नुपर्नेछ। कम्प्युटर स्क्रिनमा काम गर्दा आँखा नथाक्ने र स्क्रिनमा बत्ती नटल्किने गरी कार्यक्षेत्रमा नटल्किने प्रकाश प्रणाली (Anti-glare lighting) को व्यवस्था गर्नुपर्नेछ।

१०.३ सहकार्य तथा अन्तरक्रियात्मक कार्यस्थलको व्यवस्था:

कर्मचारीहरूबीच आपसी समन्वय, छिटो छलफल र समूहगत कार्य प्रवर्द्धन गर्न कार्यालयको आन्तरिक विन्यास देहायबमोजिम हुनुपर्नेछ:

क) परम्परागत रूपमा बन्द कोठाहरू बनाउने प्रवृत्तिको सट्टा खुला कार्यस्थलको अवधारणालाई प्राथमिकता दिनुपर्नेछ। खुला कार्यस्थलको विन्यास (Layout) गर्दा संवेदनशील तथ्याङ्क तथा डाटामा काम गर्ने कर्मचारीको कम्प्युटर स्क्रिन सेवाग्राही वा बाहिरी व्यक्तिले सिधै देख्न नसक्ने गरी दृश्यगत गोपनीयता कायम गरिनेछ। साथै, कार्यालयको आवश्यकता वा कार्यप्रकृति का आधारमा कार्य स्थललाई समूहीकरण गरी सहयोगात्मक कार्यवातावरण निर्माण गर्नुपर्नेछ।

ख) छोटो छलफल र समूहगत अन्तरक्रियाका लागि कार्यक्षेत्रकै नजिक स-साना खुला वा अर्ध-खुला स्थलहरूको व्यवस्था गर्नुपर्नेछ।

ग) औपचारिक बैठक कक्षहरूलाई भिडियो कन्फरेन्सिङ लगायतका अत्याधुनिक सञ्चार प्रविधि जडान गरी स्मार्ट बनाउनुपर्नेछ। साथै, विशेष सुरक्षा संवेदनशीलता भएका कार्यालयमा संवेदनशील तथा गोप्य कार्य वा छलफलका लागि ध्वनि बाहिर नजाने प्रविधिसहितको छुट्टै 'गोप्य बैठक कक्ष' को व्यवस्था गर्न सकिनेछ।

घ) कार्यस्थलको विन्यास डिजाइन गर्दा कर्मचारीहरूबीच दृश्यात्मक सम्पर्क कायम हुने गरी फर्निचर र पार्टिसनको उचाइ व्यवस्थापन गर्नुपर्नेछ। साथै, कार्यक्षेत्रभित्र कर्मचारीहरूको सहज, सुरक्षित र बाधारहित आवागमनका लागि हिँड्ने बाटोको चौडाइ रास्ट्रिय भवन संहिता अनुसार कायम गर्नुपर्नेछ।

१०.४ कार्यस्थलको व्यक्तिगत वातावरण नियन्त्रण:

कर्मचारीहरूको शारीरिक तथा मानसिक स्वास्थ्य, कार्यक्षमता र सन्तुष्टि अभिवृद्धि गर्न उनीहरूको प्रत्यक्ष कार्यक्षेत्रको प्रकाश, तापक्रम र फर्निचरमा उनीहरूकै सहजता अनुरूप नियन्त्रण गर्न सकिने गरी निम्न व्यवस्था गर्नुपर्नेछ:

क) कार्यालयको सामान्य प्रकाश बाहेक, कर्मचारीले आफ्नो आवश्यकता अनुसार प्रकाशको मात्रा र दिशा मिलाउन मिल्ने गरी प्रत्येक वर्कस्टेसनमा एडजस्टेबल टास्क लाइटिङ को व्यवस्था गर्न सकिनेछ।

ख) झ्यालको नजिक वा बाहिरी प्राकृतिक प्रकाश सिधै पर्ने कार्यक्षेत्रमा कम्प्युटर स्क्रिनमा पर्ने टल्काइ रोक्नका लागि सहजै खोल्न, बन्द गर्न र प्रकाशको मात्रा मिलाउन मिल्ने, समायोजन गर्न मिल्ने उपयुक्त पर्दा (Adjustable Blinds) को व्यवस्था गर्नुपर्नेछ।

ग) एच.भी.ए.सी प्रणाली जडान गर्दा एउटै तापक्रम पूरै भवनलाई लागू गर्नुको सट्टा क्षेत्रगत नियन्त्रण प्रणाली (Zonal Control System) अपनाउनुपर्नेछ। यसले गर्दा कर्मचारीले आफ्नो कार्यक्षेत्रभित्र सहजता अनुसार तापक्रम केही हदसम्म तलमाथि गर्न सक्नेछन्। साथै, एच.भी.ए.सीबाट आउने चिसो वा तातो हावा सोझै कर्मचारीको शरीरमा नपर्ने गरी डिफ्युजर को दिशा र स्थान प्राविधिक रूपमा मिलाउनुपर्नेछ।

घ) लगातार बसेर काम गर्दा हुने शारीरिक थकान र हाडजोर्नीको समस्या कम गर्न कर्मचारीको उचाइ र बसाइ अनुरूप मिलाउन मिल्ने एर्गोनोमिक कुर्सीको प्रयोग आवश्यकता अनुसार गर्नुपर्नेछ।

परिच्छेद ३: सरकारी कार्यालयहरूमा हुने स्थानहरू

परिच्छेद – २ मा उल्लिखित आधारभूत सिद्धान्त तथा साझा मापदण्डमा रही डिजाइन गर्दा सरकारी कार्यालय परिसर भित्र विभिन्न स्थानहरूको आवश्यकता हुन्छ। यस्ता स्थानहरू कार्यालय भवनहरूमा भवनको भित्र वा बाहिर हुन सक्नेछन।

१. सरकारी कार्यालय भवन भित्र हुनुपर्ने स्थानहरू

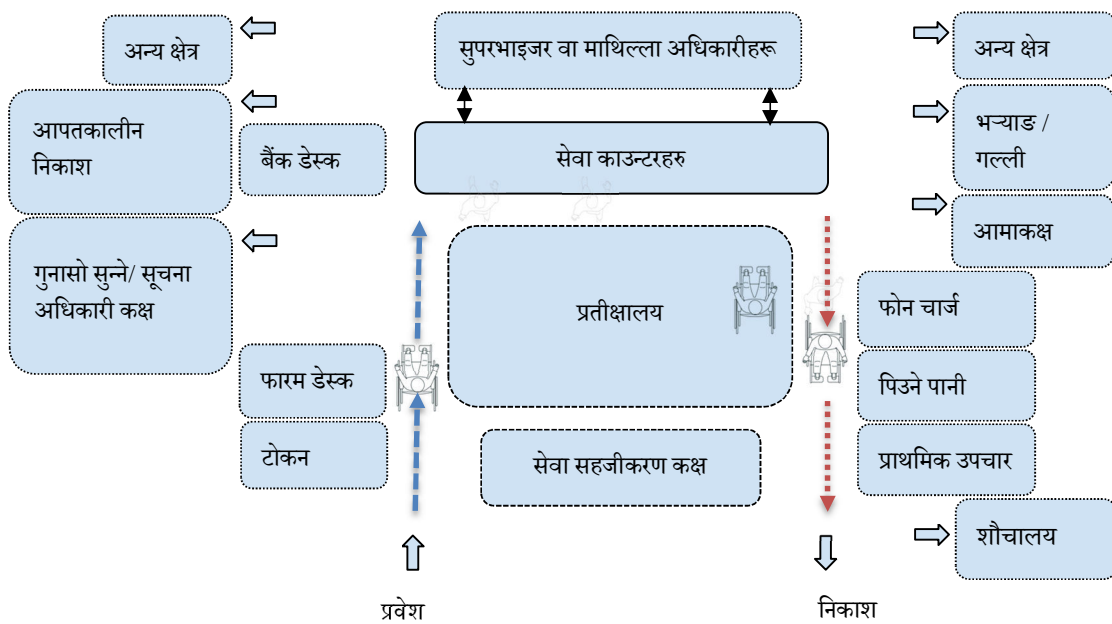
सरकारी कार्यालय भवनको डिजाइन गर्दा सेवाग्राहीको सहजता, कार्यसम्पादनको प्रभावकारिता र कर्मचारीको सुविधालाई ध्यानमा राखी निम्नअनुसारका स्थानहरूको उचित व्यवस्थापन गरिनुपर्नेछ:

१.१ सार्वजनिक अन्तरक्रिया क्षेत्र

यस क्षेत्रले सेवाग्राही वा आगन्तुकलाई प्रत्यक्ष सेवा प्रदान गर्ने र उनीहरूसँग अन्तरक्रिया हुने मुख्य स्थानलाई जनाउँछ।

कार्यालयको प्रकृति (परिच्छेद २ को वर्गीकरण) अनुसार यसको डिजाइन निम्नानुसार गरिनुपर्नेछ:

vक) सेवाग्राही वा आगन्तुकले कार्यालयको मुख्य प्रशासनिक तथा आन्तरिक कार्यक्षेत्रमा प्रवेश नगरी सेवा वा जानकारी प्राप्त गर्न

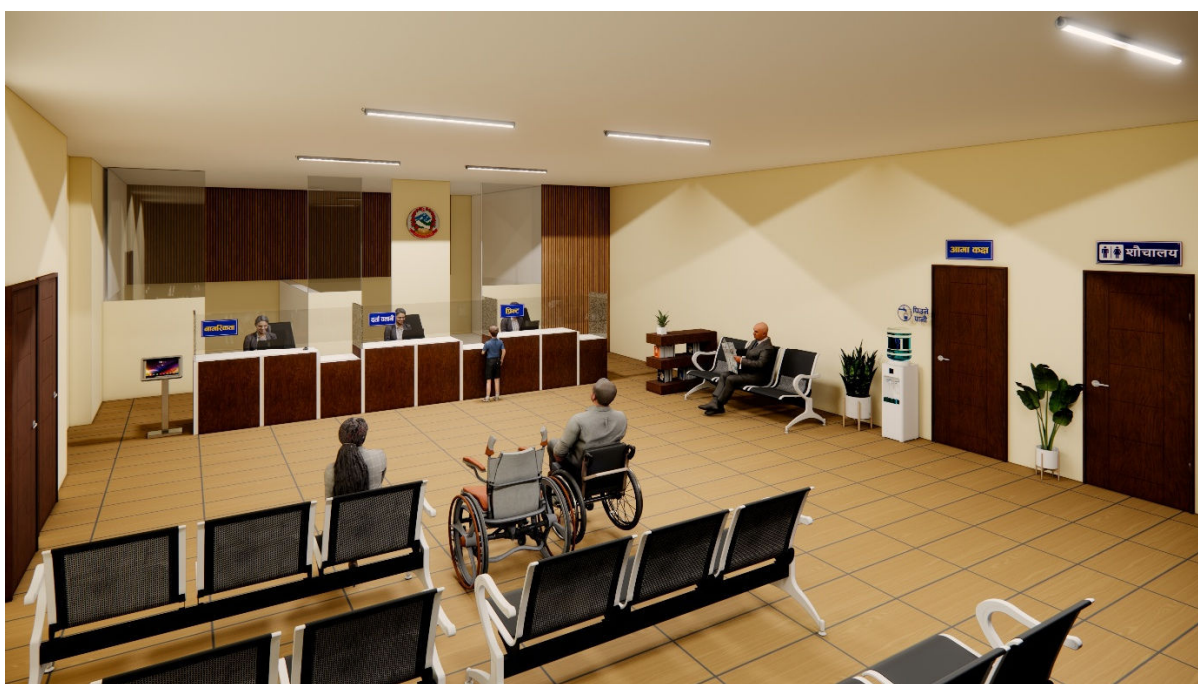


चित्र ८: एकल बिन्दु सेवा कक्षको नमूना ढाचा

सकून भन्नका लागि यस क्षेत्रलाई भवनको मुख्य प्रवेशद्वार नजिकै व्यवस्था गरिनुपर्नेछ।

ख) उच्च जनसम्पर्क हुने कार्यालय (समूह 'क') एकल बिन्दु सेवा केन्द्रको अवधारणाबाट डिजाइन गर्नु पर्दछ जसमा सेवाग्राहीले आवश्यक विभिन्न सेवाहरू एउटै स्थानबाट प्राप्त गर्न सक्ने सुविधा हुन्छ। यसका लागि 'एकल बिन्दु सेवा हल': सेवाग्राहीको अत्यधिक चाप हुने कार्यालयहरूमा उपयुक्त क्षमताको एकल बिन्दु सेवा हल निर्माण गरिनुपर्नेछ। जसको भौतिक विन्यास देहायबमोजिम हुनेछ:

- सेवा सहजिकरण कक्ष: प्रवेशद्वार नजिकै मार्गदर्शन/सोधपुछ सहायता/सहजीकरण कक्ष हुनुपर्नेछ। आवश्यकता अनुसार कक्ष नजिकै टोकन लिने, फारम भर्ने डेस्क जस्ता सुविधा समेत को व्यवस्था गर्नु पर्नेछ। यस्तो कक्षमा मुख्य प्रवेशद्वारबाट पस्ने बित्तिकै सिधै देखिने गरी संस्थाको गरिमा झल्काउने व्यावसायिक ढाँचा निर्माण गरिनुपर्नेछ।
- खुला काउन्टर: बन्द कोठाको सट्टा खुला काउन्टर निर्माण गरी कार्यप्रवाहको क्रम (जस्तै: फारम रुजु, दर्ता, राजश्व) अनुसार मिलाएर राख्नुपर्नेछ। काउन्टरहरूमा सेवाग्राही र कर्मचारीबीचको संवाद सुरक्षित राख्न र व्यक्तिगत गोपनीयताको सम्मान गर्न काउन्टरहरूबीच गोपनीयता रक्षकको रूपमा काउन्टरको डेस्क सतहबाट माथि कम्तीमा ६०० मि. मि.को उचाइका अर्ध-पारदर्शी (Semi-transparent) प्यानल राख्नुपर्नेछ वा उचित व्यवस्था गर्नु पर्नेछ, जसले गर्दा कार्यालयको खुलापन (Openness) र गोपनीयता दुवै कायम रहनेछ। साथै, राजस्व संकलन जस्ता नगद कारोवार हुनका लागि छुट्टाईएका काउन्टरको अगाडिको भागमा (सतहबाट माथि)



चित्र ९: एकल बिन्दु सेवा कक्षको नमुना

आवश्यक ठाउँमा पारदर्शी सिसा जडान गर्न सकिनेछ। त्यसो गरेमा सेवाग्राही र कर्मचारीबीच प्रस्ट कुराकानी हुन सक्ने गरी बोल्ने प्वाल(Speak-hole) वा द्वि-मार्गी सञ्चार साधन (Two-way Intercom) माइक्र प्रणाली जडान गर्नुपर्नेछ।

- यस्ता, काउन्टरमा सङ्कलन भएका फाइलहरू तुरुन्तै रुजु र सदर गर्नका लागि काउन्टरको ठिक पछाडि निर्णयकर्ता तहको कर्मचारी बस्ने भित्रि कार्यालय वा सुपरभाइजर कक्ष पारदर्शी सिसाको पार्टिसन गरी निर्माण गर्न समेत सकिनेछ।
- प्रतीक्षालय: हलको काउन्टरहरूको अगाडि वा बीचमा आरामदायी आसन, पिउने पानी, सूचना डिस्प्ले, मोबाइल चार्जिङ्ग स्टेसन र सुझाव पेटिका सहितको प्राकृतिक प्रकाश आउने ठूलो एकीकृत प्रतीक्षालय निर्माण गर्नुपर्नेछ। प्रतीक्षालयको क्षेत्रफल निर्धारण गर्दा सो कार्यालयको सबैभन्दा बढी भीड हुने समयको सेवाग्राहीको चाप र सेवाको प्रकृतिका आधारमा प्रति व्यक्ति न्यूनतम १.२ देखि १.५ वर्ग मिटर क्षेत्रफलका दरले गणना गरी त्यसको २० प्रतिशत हिस्सा आवागमन र अन्य व्यवस्थापनका लागि थप गर्नुपर्नेछ । यस्तो प्रतीक्षालयबाट गुनासो सुन्ने अधिकारी, सूचना अधिकारिको कक्ष र अपाङ्ग मैत्री सहितको शौचालय र अत्यावश्यक हुदा कार्यालय प्रमुख तथा अन्य कर्मचारीको कक्ष आदिसम्म जाने व्यवस्था समेत हुनुपर्नेछ ।
- प्रविधि र सहायक सेवा: पालो व्यवस्थापन, आवश्यकता अनुसार बैकिङ/राजश्व काउन्टर, फोटोकपी सुविधा आदि सेवा हलकै परिधिभित्र व्यवस्थापन गर्नुपर्नेछ।

ग) कम जनसम्पर्क हुने कार्यालय (समूह ख, ग) का लागि स्वागत तथा सहजीकरण कक्ष: आम नागरिकको प्रत्यक्ष भीडभाड कम हुने कार्यालयहरूमा ठूलो सेवा हलको सट्टा देहायबमोजिमको सहजीकरण कक्ष निर्माण गरे पुग्नेछ:



चित्र १०: सेवा ग्राही स्वागत तथा सहजीकरण कक्षको नमुना

- मुख्य प्रवेशद्वारबाट पस्नेबित्तिकै सिधै देखिने गरी संस्थाको गरिमा झल्काउने व्यावसायिक ढाँचाको स्वागत डेस्क निर्माण गरिनुपर्नेछ।

- यस कक्षबाट आगन्तुक दर्ता, आवश्यकता अनुसार पास वितरण, सम्बन्धित अधिकारीसँगको भेटघाट व्यवस्थापन र सामान्य सोधपूछको कार्य हुनेछ।
- आगन्तुक वा अतिथिलाई केही समय कुर्नका लागि पर्याप्त प्रकाश भएको, आरामदायी सोफा/कुर्सी र पत्रपत्रिका/सूचना सामग्री सहितको सानो तर व्यवस्थित प्रतीक्षालयको व्यवस्था गरिनुपर्नेछ।
- कुन शाखा वा अधिकारी कुन तलामा छन भनी प्रस्ट बुझाउने नक्सा वा डिजिटल डिस्प्ले स्वागत कक्षसँगै देखिने गरी राखिनुपर्नेछ।

घ) यो समग्र क्षेत्र पूर्ण रूपमा समावेशी हुनुपर्नेछ। यसका लागि न्याम्प, हिलचेयर घुम्न सक्ने पर्याप्त स्थान, पहुँचयुक्त उचाइका सेवा काउन्टर/डेस्क र स्पष्ट सङ्केत पाटी को अनिवार्य व्यवस्था गरिनुपर्नेछ।

१.२ औपचारिक तथा भेटघाट कार्यक्रम सञ्चालन स्थल

सरकारी कार्यालयमा हुने बैठक, तालिम, छलफल, पत्रकार सम्मेलन तथा अन्य औपचारिक कार्यक्रम सञ्चालन गर्नका लागि आवश्यकता अनुसार छुट्टै कार्यक्रम स्थलको व्यवस्था निम्नअनुसार गरिनुपर्नेछ:

- क) कार्यक्रम स्थलको डिजाइन गर्दा कार्यालयको दैनिक प्रशासनिक कार्य र सेवा प्रवाहमा कुनै पनि प्रकारको ध्वनि वा भीडभाडले अवरोध नपर्ने गरी छुट्टै वा एकान्त क्षेत्रमा गरिनुपर्नेछ।
- ख) आवश्यकताअनुसार सभा कक्ष, प्रशिक्षण कक्ष वा सम्मेलन कक्षको रूपमा परिमार्जन गरी प्रयोग गर्न सकिने फर्निचर र पार्टिसनको व्यवस्था हुनुपर्नेछ।
- ग) कक्षभित्र आवश्यकता अनुसार उपयुक्त ध्वनि नियन्त्रण, प्राकृतिक तथा कृत्रिम प्रकाश व्यवस्था, प्राकृतिक भेन्टिलेसन, आवश्यकता अनुसार वातानुकूलित प्रणाली, आधुनिक डिजिटल प्रस्तुतीकरण प्रणाली र भरपर्दो इन्टरनेट सुविधा हुनुपर्नेछ।
- घ) ठूलो क्षमताका कार्यक्रम कक्षहरूमा आपतकालीन निकास, अग्नि सुरक्षा प्रणाली र बाहिर निस्कँदा जम्मा हुने खुला स्थान को व्यवस्था हुनुपर्नेछ। साथै, यस क्षेत्र नजिकै छुट्टै प्रतीक्षालय र शौचालयको व्यवस्था मिलाउनुपर्नेछ।

१.३ सहकार्य क्षेत्र

विभिन्न शाखा वा विभागका कर्मचारीहरूबीच आपसी समन्वय, समूहगत कार्य र नवीन सोचको विकास गर्न कार्यालयभित्र एक छुट्टै सहकार्य क्षेत्रको व्यवस्था गरिनुपर्नेछ:

- क) कर्मचारीहरूले अनौपचारिक रूपमा छलफल गर्न, विचार-विमर्श गर्न र अन्तर-विभागीय समन्वय गर्न सक्ने गरी खुला वा अर्ध-खुला स्थानको निर्माण गरिनुपर्नेछ।
- ख) यस क्षेत्रमा सहज किसिमका मोड्युलर फर्निचर, गोलो टेबुल, सेतो पाटि र प्रिन्टिङ/फोटोकपी जस्ता साझा सुविधाहरू राखिनुपर्नेछ।

ग) साना समूहका लागि भर्चुअल बैठक गर्न वा कम्प्युटर जोडी स्क्रिन साझा गर्न मिल्ने गरी प्लग-पइन्ट र वाइफाइ (Wi-Fi) को उत्कृष्ट व्यवस्था हुनुपर्नेछ।

घ) यस क्षेत्रलाई मुख्य प्रशासनिक कार्यक्षेत्रको नजिकै तर शान्त काम गर्ने कर्मचारीलाई हल्लाले असर नगर्ने गरी उपयुक्त ध्वनि अवशोषक सामग्री प्रयोग गरी निर्माण गरिनुपर्नेछ।

१.४ कार्यालयका सहायक सुविधाहरू

कार्यालय भवनभित्र कर्मचारीहरूको कार्यक्षमता अभिवृद्धि गर्न, शारीरिक तथा मानसिक स्वास्थ्यलाई सन्तुलित राख्न र सेवाग्राहीको सुविधालाई ध्यानमा राखी निम्नअनुसारका सहायक सुविधाहरूको व्यवस्था गरिनुपर्नेछ:

क) कार्यालय भवनमा आवश्यकता अनुसार चमेनागृह, खाजा कक्ष, प्राथमिक उपचार कक्ष तथा आराम कक्ष, स्तनपान तथा शिशु स्याहार कक्ष, शुद्ध पिउने पानीको स्टेसन र कर्मचारीहरूका लागि छुट्टै शौचालय को व्यवस्था हुनुपर्नेछ।

ख) साइकल प्रयोग गरी कार्यालय आउने कर्मचारीहरूलाई प्रोत्साहन गर्न साइकल मैत्री भौगोलिक अवस्थामा रहेका कार्यालयमा शौचालय संगै कम्तिमा एक नुहाउने कक्ष र लुगा फेर्ने सुरक्षित लकरको व्यवस्था गर्नुपर्नेछ।

ग) यी सुविधाहरूलाई कर्मचारी तथा सेवाग्राहीको सहज पहुँच पुग्ने तर कार्यालयको मुख्य प्रशासनिक तथा दैनिक कामकारबाहीमा कुनै किसिमको ध्वनि वा अन्य अवरोध नपर्ने स्थानमा राखिनुपर्नेछ।

घ) कर्मचारीको मानसिक तथा शारीरिक थकान कम गर्न उपयुक्त विश्राम कक्ष, खुला बसाइ क्षेत्र र सम्भव भएसम्म हरियाली समावेश गरिएको हुनुपर्नेछ। यी क्षेत्रहरूमा पर्याप्त प्राकृतिक प्रकाश, भेन्टिलेसन र उच्च स्तरको सरसफाइ सुनिश्चित गरिनुपर्नेछ।

ङ) कार्यालयको कुल क्षेत्रफल, कार्यरत कर्मचारीहरूको संख्या र दैनिक रूपमा आउने सेवाग्राहीको चापको सूक्ष्म विश्लेषण गरी सोही अनुपातमा सुविधाहरू को क्षमता र परिमाण निर्धारण गरिनुपर्नेछ।

च) परिवर्तन कक्ष (Changing Room)

- कर्मचारीका लागि आवश्यक परेमा कपडा परिवर्तन गर्न सकिने सुरक्षित, स्वच्छ र गोपनीयता सुनिश्चित हुने परिवर्तन कक्षको व्यवस्था गरिनुपर्नेछ।
- महिला र पुरुषका लागि छुट्टाछुट्टै वा आवश्यकता अनुसार एकल प्रयोग गर्न मिल्ने कक्ष हुनुपर्नेछ। उक्त कक्ष पर्याप्त प्रकाश, भेन्टिलेसन तथा ढोका-ताल्चा सहित गोपनीयता सुनिश्चित हुने गरी डिजाइन गरिएको हुनुपर्नेछ।
- परिवर्तन कक्षमा बस्ने सिट, ऐना, हुक/कपडा झुण्ड्याउने व्यवस्था तथा सरसफाइ सामग्री राख्ने स्थानको व्यवस्था हुनुपर्नेछ। साथै अपाङ्गता भएका व्यक्तिहरूका लागि सहज पहुँचयोग्य हुने गरी (barrier-free access) डिजाइन गरिनुपर्नेछ।
- परिवर्तन कक्षको स्थान कर्मचारी शौचालय नजिक तर प्रत्यक्ष दृश्यबाट सुरक्षित दूरीमा रहने गरी उपयुक्त रूपमा निर्धारण गरिनुपर्नेछ।

१.५ आवागमन क्षेत्र

भवनभित्र मानिस, सामग्री तथा सेवाको सुरक्षित, सहज र व्यवस्थित आवागमन सुनिश्चित गर्न आवागमन क्षेत्र को डिजाइन निम्न मापदण्डका आधारमा गरिनुपर्नेछ:

- क) आवागमन क्षेत्रको चौडाइ भीडभाडको समयमा पनि सहजै आवतजावत गर्न सकिने गरी पर्याप्त हुनुपर्नेछ। सार्वजनिक, अर्ध-सार्वजनिक र आन्तरिक/निजी क्षेत्रहरूबीचको आवागमन मार्ग स्पष्ट रूपमा नबाझिने गरी छुट्याइएको हुनुपर्नेछ।
- ख) फरक क्षमता भएका व्यक्तिहरूको स्वतन्त्र र सुरक्षित आवागमनका लागि 'युनिभर्सल डिजाइन' को सिद्धान्त पूर्ण रूपमा पालना गरिनुपर्नेछ। यसका लागि मापदण्ड अनुरूपको च्याम्प, अपाङ्गतामैत्री लिफ्ट, भ्याड तथा च्याम्पमा उपयुक्त ह्यान्डरेल र दृष्टिविहीनहरूको सहजताका लागि भुइँमा ट्याक्टायल फ्लोरिङको व्यवस्था हुनुपर्नेछ। साथै, सबै लिफ्टहरूमा अडियो (आवाज) सङ्केत जडान गर्नु पर्नेछ।
- ग) विपद् वा आपतकालीन अवस्थामा सुरक्षित र छिटो बाहिर निस्कनका लागि 'राष्ट्रिय भवन संहिता (NBC)' तथा 'अग्नि सुरक्षा मापदण्ड' को पूर्ण पालना गर्दै आपतकालीन निकास र भाग्ने मार्ग को स्पष्ट डिजाइन गरिनुपर्नेछ।
- घ) करिडोर, भ्याड तथा गल्ली जस्ता आवागमन क्षेत्रहरू सम्भव भएसम्म प्राकृतिक प्रकाश र भेन्टिलेसनयुक्त हुनुपर्नेछ। यी क्षेत्रहरू पूर्णतया अवरोधरहित र ऊर्जा खपत कम गर्ने प्रविधिमा आधारित हुनुपर्नेछ।

२. सरकारी कार्यालय परिसरभित्र हुनुपर्ने बाह्य स्थानहरू तथा सुविधाहरू

सरकारी कार्यालयको बाह्य परिसर सेवाग्राहीको पहिलो सम्पर्क बिन्दु भएकाले यसलाई सुरक्षित, व्यवस्थित, समावेशी र वातावरणमैत्री बनाउन निम्नअनुसारका पूर्वाधारहरूको व्यवस्था गरिनुपर्नेछ:

२.१ नागरिक बडापत्र

कार्यालयको सेवा प्रवाहलाई पारदर्शी र सेवाग्राहीमैत्री बनाउन परिसरभित्र नागरिक बडापत्र राखिनुपर्नेछ। यसको व्यवस्थापन निम्नअनुसार हुनुपर्नेछ:

- क) सेवाग्राहीले कार्यालय परिसरमा प्रवेश गर्नेबित्तिकै सहजै देख्न र पढ्न सक्ने गरी मुख्य प्रवेशद्वार वा सेवा प्रवाह हुने भवनको अग्रभागमा राखिनुपर्नेछ।
- ख) बडापत्रमा उपलब्ध सेवाहरू, आवश्यक कागजात, लाग्ने समय, शुल्क, सम्बन्धित शाखा र गुनासो सुन्ने अधिकारीको विवरण स्पष्ट रूपमा खुलाइएको हुनुपर्नेछ।
- ग) बोर्ड घामपानीबाट नबिग्रिने सामग्रीबाट निर्माण गरिएको हुनुपर्नेछ। विवरणहरू स्पष्ट बुझिने नेपाली भाषामा हुनुपर्नेछ भने आवश्यकताअनुसार अंग्रेजी भाषा र दृष्टिविहीनहरूका लागि ब्रेल लिपि समेत समावेश गर्न सकिने व्यवस्था मिलाउनुपर्नेछ। साथै आवश्यकता अनुसार, डिजिटल डिस्प्ले र अडियो (सुन्न सकिने) बडापत्रको समेत व्यवस्था मिलाउनुपर्नेछ।

२.२ सङ्केत चिन्ह

परिसरभित्र सहज आवागमन र स्थान पहिचानका लागि स्पष्ट सङ्केत चिन्हहरूको व्यवस्था निम्नअनुसार गरिनुपर्नेछ:

क) प्रवेशद्वार, पार्किङ, सार्वजनिक शौचालय, आपतकालीन निकास, प्रतीक्षालय, विभिन्न शाखाहरू र लिफ्ट/न्याम्पतर्फ निर्देश गर्ने सङ्केतहरू उपयुक्त स्थानमा राखिनुपर्नेछ।

ख) सङ्केत पाटीहरू नेपाली, अङ्ग्रेजी र आवश्यकता अनुसार सम्बन्धित स्थानीय मातृभाषामा समेत हुनुपर्नेछ। दृष्टिविहीन तथा फरक क्षमता भएका व्यक्तिका लागि स्पर्श सङ्केत र ह्विलचेयरबाट पनि सहजै देखिने उचाइमा राखिनुपर्नेछ। रातिको समयमा समेत स्पष्ट देखिने गरी प्रतिविम्बित वा प्रकाशयुक्त सामग्रीको प्रयोग गरिनुपर्नेछ।

२.३ सुरक्षा कक्ष / गार्ड पोस्ट

परिसरको सुरक्षा व्यवस्थापन र प्रवेश नियन्त्रणका लागि मुख्य प्रवेशद्वार नजिकै गार्ड पोस्टको निर्माण निम्न अनुसार गरिनुपर्नेछ:

क) सुरक्षा कक्षबाट मुख्य प्रवेशद्वार र बाहिरिने क्षेत्र पूर्ण रूपमा र स्पष्ट देखिने हुनुपर्नेछ।

ख) सुरक्षाकर्मीका लागि पर्याप्त कार्यस्थान, सञ्चार सुविधा, विद्युत् आपूर्ति र सीसीटीभी मनिटर तथा सुरक्षा उपकरण राख्ने व्यवस्था हुनुपर्नेछ।

ग) आगन्तुक दर्ता, सवारी प्रवेश नियन्त्रण र आकस्मिक अवस्थाको व्यवस्थापन सहजै गर्न सकिने गरी यसको डिजाइन गरिनुपर्नेछ।

२.४ सार्वजनिक शौचालय

कार्यालय बाहिर वा परिसरमा रहने सेवाग्राही तथा कर्मचारीका लागि पर्याप्त क्षमताको सार्वजनिक शौचालय निम्नअनुसार निर्माण गरिनुपर्नेछ:

क) पुरुष, महिला तथा फरक क्षमता भएका व्यक्तिहरूका लागि छुट्टाछुट्टै र पूर्ण रूपमा अपाङ्गतामैत्री शौचालय निर्माण गरिनुपर्नेछ।

ख) शौचालय भवनबाट सहज पहुँचमा हुनुपर्नेछ, तर त्यसको दुर्गन्ध वा सरसफाइको असर मुख्य प्रशासनिक वा सेवा क्षेत्रमा नपर्ने गरी उपयुक्त दूरीमा राखिनुपर्नेछ।

ग) नियमित पानी आपूर्ति, हात धुने बेसिन, प्राकृतिक तथा कृत्रिम भेन्टिलेसन, पर्याप्त प्रकाश र फोहोर व्यवस्थापनको उचित प्रबन्ध हुनुपर्नेछ। यसको डिजाइन 'राष्ट्रिय भवन संहिता (NBC)' को सरसफाइ मापदण्डअनुसार हुनुपर्नेछ।

२.५ खुला स्थान / उद्धार क्षेत्र

विपद्को समयमा सुरक्षित रहन र बाह्य वातावरण खुला राख्न निम्नअनुसारको खुला स्थान व्यवस्था गरिनुपर्नेछ:

क) भूकम्प वा आगलागी जस्ता विपद्मा मानिसहरू भेला हुन भवनको संरचनात्मक जोखिमबाट सुरक्षित दूरीमा रहने गरी भेला हुने स्थानको स्पष्ट रेखाङ्कन गरिनुपर्नेछ।

ख) भवनको आपतकालीन निकास मार्गबाट निस्केर सिधै यस खुला स्थानमा पुग्न सकिने गरी अवरोधरहित बाटो हुनुपर्नेछ।

ग) विपद् बाहेकको सामान्य अवस्थामा यस क्षेत्रलाई हरियाली, बस्ने स्थान वा सामुदायिक कार्यक्रमका लागि प्रयोग गर्न सकिने गरी डिजाइन गरिनुपर्नेछ।

२.६ सवारी बिसौनी (पार्किङ)

सवारी साधनको व्यवस्थित पार्किङका लागि निम्न व्यवस्था गरिनुपर्नेछ:

- क) दुई पाङ्ग्रे, चार पाङ्ग्रे, कार्यालयका सवारी र फरक क्षमता भएका व्यक्तिहरूका सवारीका लागि स्पष्ट रूपमा छुट्याइएको पार्किङ क्षेत्र हुनुपर्नेछ। कुल पार्किङ क्षमताको न्यूनतम १०% देखि २०% स्थानमा विद्युतीय सवारी चार्जिङ पोइन्टको व्यवस्था गर्नुपर्नेछ।
- ख) पार्किङ क्षेत्रले मुख्य प्रवेशद्वार र पैदल मार्ग लाई अवरुद्ध गर्नु हुँदैन। सवारी साधन प्रवेश गर्ने र बाहिरिने मार्ग स्पष्ट रूपमा चिन्हित गरिनुपर्नेछ।
- ग) पार्किङ क्षेत्रमा वर्षाको पानी तर्काउने निकास, पर्याप्त प्रकाश र आवश्यकताअनुसार छहारीको व्यवस्था मिलाइनुपर्नेछ।

२.७ भण्डारण र्याक / सुरक्षित दराज

- क) सेवाग्राहीका झोला वा व्यक्तिगत सामग्री राख्न सुरक्षा कक्ष वा प्रतीक्षालय नजिकै भण्डारण र्याक वा सुरक्षित दराजको व्यवस्था गरिनुपर्नेछ।
- ख) यस्तो स्थानले मुख्य आवागमन मार्ग अवरुद्ध गर्नु हुँदैन। सुरक्षित दराजहरू आर्द्रता, आगलागी र चोरीबाट सुरक्षित हुने किसिमका हुनुपर्नेछ।

२.८ विद्युतीय तथा सेवा कक्ष

- क) ट्रान्सफर्मर, जेनेरेटर, इन्टरनेट नेटवर्क उपकरण, फायर फाइटिङ पम्प हाउस र पानी आपूर्तिको उपकरणहरू राख्न परिसरको एक कुनामा वा छुट्टै ब्लकमा सेवा कक्ष निर्माण गरिनुपर्नेछ।
- ख) यस्ता कक्षहरू सर्वसाधारणको पहुँचभन्दा बाहिर हुनुपर्नेछ र अधिकृत प्राविधिकलाई मात्र प्रवेशको व्यवस्था हुनुपर्नेछ। यहाँ पर्याप्त भेन्टिलेसन, ताप नियन्त्रण, र अग्नि नियन्त्रण उपकरण राखिनुपर्नेछ।

२.९ बाह्य वा अर्ध-बाह्य प्रतीक्षालय

- क) भवनभित्र पस्नुअघि वा बाहिरै सेवा लिने सेवाग्राहीका लागि घामपानीबाट सुरक्षित हुने गरी बाह्य वा अर्ध-बाह्य प्रतीक्षालयको व्यवस्था गरिनुपर्नेछ।
- ख) यस क्षेत्रमा बस्ने सिट, पिउने पानी, सूचना प्रदर्शन बोर्ड, टोकन डिस्प्ले र प्राकृतिक हावा प्रवाह को पर्याप्त व्यवस्था हुनुपर्नेछ।

२.१० हरियाली तथा भू-सौन्दर्यीकरण

- क) परिसरभित्र अत्यधिक कंक्रीटको प्रयोगलाई निरुत्साहित गर्दै पर्याप्त अनुपातमा हरित क्षेत्र कायम राख्नुपर्नेछ।
- ख) स्थानीय हावापानी सुहाउँदो वृक्षारोपण, घाँसे मैदान र वर्षाको पानी संकलन/पुनर्भरण प्रणालीलाई भू-सौन्दर्यीकरणसँग एकीकृत गरिनुपर्नेछ।
- ग) भू-सौन्दर्यीकरणले गर्मी नियन्त्रण, धुलो न्यूनीकरण र सेवाग्राही तथा कर्मचारीमा सकारात्मक मनोवैज्ञानिक प्रभाव पार्ने गरी पैदलमार्ग र बस्ने स्थानहरूसँग समन्वय गरिएको हुनुपर्नेछ।

परिच्छेद ४: विविध

१. निर्देशन दिन सक्ने:

मन्त्रालयले मापदण्डको कार्यान्वयनका सन्दर्भमा आवश्यक निर्देशन दिन सक्नेछ । त्यस्तो निर्देशनको पालना गर्नु मन्त्रालय अन्तर्गतका विभाग, कार्यालयहरू तथा भवन निर्माण कार्यमा संलग्न सबै मन्त्रालय तथा अन्तर्गतका निकायहरूको कर्तव्य हुनेछ ।

२. दुविधा भएमा गर्ने:

यस मापदण्डको कार्यान्वयनमा कुनै दुविधा भएमा पूर्वाधार विकास मन्त्रालयबाट भएको निर्णय मान्य हुनेछ ।

३. कार्य सीमा:

क) यस मापदण्डले संवैधानिक निकायका प्रमुखहरूको कार्यकक्ष, नेपाली सेना तथा नेपाल प्रहरी, सशस्त्र प्रहरीका पदाधिकारीहरूको कार्यकक्ष र स्वास्थ्योपचार सम्बन्धी कार्यकक्षहरू समेटेको छैन । उपरोक्त पदाधिकारीहरूको कार्यकक्षको निर्माण गर्न छुट्टै अध्ययन गराई निर्धारण गरिने छ ।

ख) यस मापदण्डमा उल्लिखित कार्यकक्षको क्षेत्रफलका अंकहरूमा परिस्थिति अनुसार तथा डिजाइनको आवश्यकता अनुसार १५ प्रतिशत सम्म थपघट गर्न सम्बन्धित सार्वजनिक निकायका प्रमुखले सक्नेछ ।

ग) यस मापदण्ड नेपाल सरकारका सङ्घीय मन्त्रालय, विभाग र अन्तर्गतका कार्यालयहरूका लागि बाध्यकारी हुनेछ। प्रदेश सरकार तथा स्थानीय तहहरूले आफ्ना सरकारी भवनहरू निर्माण वा स्तरोन्नति गर्दा यस मापदण्डलाई मार्गदर्शनका रूपमा ग्रहण गरी स्थानीय आवश्यकता अनुसार परिमार्जन गरी लागू गर्न सक्नेछन्।

घ) यस मापदण्डमा आवश्यकता अनुसार नेपाल सरकार मन्त्रिपरिषद्को निर्णयबाट संशोधन गर्न सक्नेछ ।

४. विद्यमान सरकारी भवनहरूको स्तरोन्नति र समायोजन:

यस मापदण्ड लागू हुनुअघि निर्माण भई सञ्चालनमा रहेका सरकारी कार्यालय भवनहरूलाई यसै मापदण्ड अनुरूप रूपान्तरण तथा समायोजन गर्न सम्बन्धित निकायले देहायबमोजिमको प्रक्रिया अवलम्बन गर्नुपर्नेछ:

क) कुनै पनि विद्यमान भवनमा स्तरोन्नति वा सुधारको कार्य प्रारम्भ गर्नुअघि सम्बन्धित निकायले भवनको आवश्यकता तथा वर्तमान अवस्था सम्बन्धि प्रतिवेदन तयार गरि कार्यालयको कार्य विवरण अनुसार सेवा प्रवाहको प्रभावकारी व्यवस्थापन गर्नुपर्दछ। यसका लागि आवश्यकता अनुसार निम्नअनुसारको सुधारको कार्यहरू गर्नुपर्दछ:

- उच्च जनसम्पर्क हुने (समूह क) का कार्यालयहरूमा एकल बिन्दु सेवा केन्द्र (One Stop Service Center) को अवधारणाबाट सेवा प्रवाह गर्न प्रबन्ध मिलाउने ।
- कार्यालयमा सहज आवागमन र स्थान पहिचानक लागि स्पष्ट संकेत चिन्ह राख्ने ।
- सुरक्षित तथा भरपर्दो संचारका लागि आवश्यकता अनुसार उच्च गतिको फाइबर इन्टरनेट राख्ने तथा एकल बिन्दु सेवा (One Stop Service Solution) का लागि सार्वजनिक उद्घोषण (PA) प्रणाली र फाइल निगरानी (Tracking System) को व्यवस्था गर्ने।
- कार्यालयको सेवा प्रवाहलाई पारदर्शी र सेवाग्राही मैत्री बनाउन नागरिक बडापत्र राख्ने ।
- कार्यालय परिसरमा सेवाग्राही तथा कर्मचारीका लागि पुरुष, महिला र फरक क्षमता भएका व्यक्तिहरूका लागि छुट्टाछुट्टै तथा पूर्ण रूपमा अपाङ्गतामैत्री शौचालयको पर्याप्त व्यवस्था गर्ने।
- कार्यालय परिसरमा सेवाग्राही तथा कर्मचारीका लागि स्वच्छ पिउने पानीको व्यवस्था, उपयुक्त भेन्टिलेसन तथा शुद्ध हावाको प्रवाह सुनिश्चितता, पर्याप्त फोहोरदानी (dustbin) को प्रबन्ध, र आपतकालीन प्रयोगका लागि सहज पहुँचयोग्य स्थानमा प्राथमिक उपचार बाकस (first aid box) को व्यवस्था अनिवार्य रूपमा गर्ने ।

ख) हाल सञ्चालनमा रहेका सरकारी कार्यालय ऐतिहासिक, सांस्कृतिक वा पुरातात्विक महत्त्वको भवनमा रहेको भएमा, त्यस्ता भवनको मौलिक वास्तुकला र संरचनामा प्रतिकूल असर नपर्ने गरी पुरातत्त्व विभागको समन्वयमा मात्र आन्तरिक विन्यास, मर्मतसम्भार तथा प्रविधि जडानका कार्यहरू गर्न सकिनेछ।

५. भाडामा लिइने भवन सम्बन्धी व्यवस्था: कार्यालय प्रयोजनका लागि भाडामा लिइने निजी भवनहरूको हकमा यो मापदण्डको शतप्रतिशत पालना गर्न सम्भव नभए तापनि, न्यूनतम रूपमा अपाङ्गतामैत्री प्रवेशद्वार, पर्याप्त उज्यालो/हावाको प्रवाह र सुरक्षित आपत्कालीन निकास भएको भवनलाई मात्र भाडामा लिन प्राथमिकता दिइनेछ ।

अनुसूची १: कार्यकक्षको वर्गीकरण र मापदण्ड

क) उपप्रधानमन्त्री/मन्त्री/राज्यमन्त्रीको कार्यकक्ष

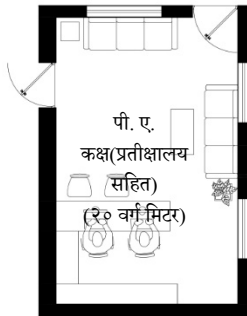
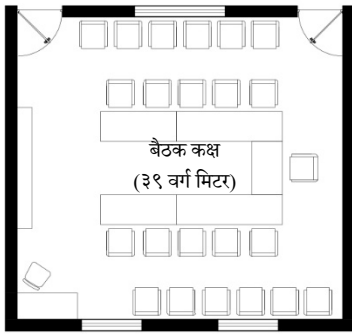
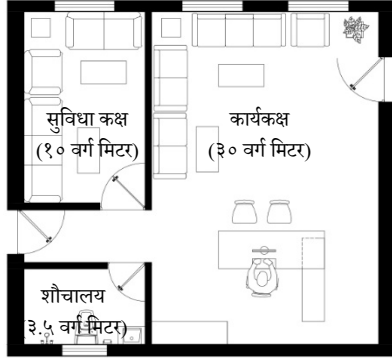


चित्र ११: उपप्रधानमन्त्री/मन्त्री/राज्यमन्त्रीको कार्यकक्षको नमूना नक्सा

क्र.सं.	विवरण	क्षेत्रफल (वर्ग मिटर)
१.	कार्यकक्ष	३३
२.	बैठक कक्ष	७८
३.	स्वकीय सचिव कक्ष (निजी)	३०
४.	स्वकीय सचिव कक्ष (प्रशासनिक)	१४.५
५.	सुविधा कक्ष	१०
६.	शौचालय	३.५०
	जम्मा क्षेत्रफल	१६९

क्र.सं.	विवरण	फर्निचर विवरण (मि.मी x मि.मी.)	संख्या
१.	कार्यकक्ष	काम गर्ने टेबुल-२०००x१०००	१
		टी-टेबुल १-४५०x९००	२
		टी-टेबुल २-४५० ब्यास	२
		सोफा- २/३ जना बस्ने	३
		सहायक टेबुल-४५०x४००	४
		दराज-५२५x१२००	१
		कुर्सी १-६००x५४०	१
		कुर्सी २-३९०x५०५	२
		सोफा - १ जना बस्ने	२
		फाइल दराज-१३००x३७५	१
२.	बैठक कक्ष	बैठक टेबुल-७३००x२२५०	१
		कुर्सी-५५०x५५०	४५
		कम्प्युटर टेबुल-९००x५२५	१
		टेलिभिजन / स्क्रीन टेबुल-७५०x६००	१
३.	पी.ए.(प्रतीक्षालय सहित) (निजी)	काम गर्ने टेबुल-२८००x६००	१
		कुर्सी १-५५०x५५०	२
		कुर्सी २-३९०x५०५	२
		सहायक टेबुल-४५०x४००	१
		सोफा - २/३ जना बस्ने	३
		दराज-५२५x१२००	२
		टी-टेबुल १-४५०x९००	१
४.	पी.ए.(प्रशासनिक)	काम गर्ने टेबुल-२२००x७५०	१
		कुर्सी-५५०x५५०	१
		दराज-४५०x९००	१
		सोफा - २ जना बस्ने	१
५.	सुविधा कक्ष	सोफा - २/३ जना बस्ने	२
		सोफा - १ जना बस्ने	१
		टी-टेबुल-४५०x९००	१
		सहायक टेबुल-४५०x४००	२

ख) सचिव (विशिष्ट श्रेणी) को कार्यकक्ष



चित्र १२: सचिव (विशिष्ट श्रेणी) को कार्यकक्षको नमूना नक्सा

क्र.सं.	विवरण	क्षेत्रफल (वर्ग मिटर)
१.	कार्यकक्ष	३०
२.	शौचालय	३.५
३.	बैठक कक्ष	३९
४.	पी. ए. कक्ष(प्रतीक्षालय सहित)	२०
५.	सुविधा कक्ष	१०
	जम्मा क्षेत्रफल	१०२.५०

फर्निचर विवरण

क्र.सं	विवरण	फर्निचर विवरण (मि. मी x मि.मी)	संख्या
१.	कार्यकक्ष	काम गर्ने टेबुल-२०००x१०००	१
		टी-टेबुल-४५०x९००	२
		सोफा - २/३ जना बस्ने	३
		सोफा - १ जना बस्ने	१
		सहायक टेबुल-४५०x४००	१
		दराज-५२५x१२००	१
		कुर्सी १-६००x५४०	१
		कुर्सी २-३९०x५०५	२
		फाइल दराज-१४००x३७५	१
२.	बैठक कक्ष	बैठक टेबुल-३४७५x१६२५	१
		कुर्सी-५५०x५५०	२३
		कम्प्युटर टेबुल-९००x५२५	१
		टेलिभिजन/ स्क्रीन टेबुल-७५०x६००	१
३.	पी.ए.(प्रतीक्षालय) सहित	काम गर्ने टेबुल-२५००x६००	१
		कुर्सी १-५५०x५५०	२
		कुर्सी २-४००x५००	२
		सोफा -३ जना बस्ने	२
		सहायक टेबुल-४५०x४००	१
		सहायक टेबुल २ -९००x४००	१
		दराज-४५०x९००	१
		टी-टेबुल-४५०x९००	१
४.	सुविधा कक्ष	सोफा - २/३ जना बस्ने	२
		सोफा - १ जना बस्ने	१
		टी-टेबुल-४५०x९००	२
		सहायक टेबुल-४५०x४००	१

ग) रा.प. प्रथम(सहसचिव) श्रेणीका विभागीय प्रमुख/महानिर्देशक/आयोजना/कार्यालय प्रमुखको कार्यकक्ष



चित्र १३: रा.प. प्रथम(सहसचिव) श्रेणीका विभागीय

प्रमुख/महानिर्देशक/आयोजना/कार्यालय प्रमुखको कार्यकक्षको नमूना

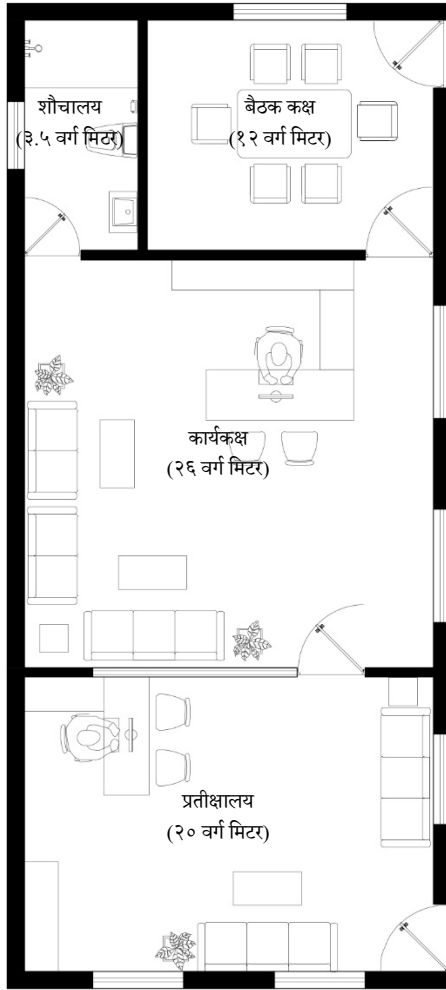
नक्सा

क्र.सं.	विवरण	क्षेत्रफल (वर्ग मिटर)
१.	कार्यकक्ष	३०
२.	शौचालय	३.५
३.	बैठक कक्ष	३० देखि ७० (आवश्यकता अनुसार)
४.	पी. ए. कक्ष (प्रतीक्षालय सहित)	२०
५.	सुविधा कक्ष	१०
	जम्मा क्षेत्रफल	९३.५ - १३३.५

फर्निचर विवरण

क्र.सं	विवरण	फर्निचर विवरण (मि. मी x मि.मी)	संख्या
१.	कार्यकक्ष	काम गर्ने टेबुल-२०००x१०००	१
		टी-टेबुल-४५०x९००	२
		सोफा - २/३ जना बस्ने	३
		सोफा - १ जना बस्ने	१
		सहायक टेबुल १ -४५०x४००	१
		सहायक टेबुल २ -९००x४००	१
		दराज-५२५x१२००	१
२.	बैठक कक्ष	कुर्सी १-६००x५४०	१
		कुर्सी २-४००x५००	२
		फाइल दराज-१९००x३७५	१
		बैठक टेबुल-३०००x१५००	१
		कुर्सी-५५०x५५०	१५ - ३५
		कम्प्युटर टेबुल-९००x५२५	१
		टेलिभिजन/स्क्रीन टेबुल- ७५०x६००	१
३.	प्रतीक्षालय	काम गर्ने टेबुल-२५००x६००	१
		कुर्सी १-५५०x५५०	१
		कुर्सी २-४००x५००	२
		सोफा - २/३ जना बस्ने	२
		सहायक टेबुल १ -४५०x४००	२
		सहायक टेबुल २ -९००x४००	२
		दराज-४५०x९००	१
४.	सुविधा कक्ष	सोफा - २/३ जना बस्ने	२
		टी-टेबुल-४५०x९००	१
		सहायक टेबुल-४५०x४००	१
		दराज-५२५x१२००	१

घ) सहसचिव (रा.प. प्रथम श्रेणी) को कार्यकक्ष



चित्र १४: सहसचिव (रा.प. प्रथम श्रेणी) को कार्यकक्षको नमूना नक्सा

क्र.सं	विवरण	क्षेत्रफल (वर्ग मिटर)
१.	कार्यकक्ष	२६
२.	शौचालय	३.५०
३.	बैठक कक्ष	१२
४.	प्रतीक्षालय	२०
	जम्मा क्षेत्रफल	६१.५

फर्निचर विवरण

क्र.सं.	विवरण	फर्निचर विवरण (मि.मी x मि.मी)	संख्या
१.	कार्यकक्ष	काम गर्ने टेबुल-२०००x५२५	१
		टी-टेबुल-४५०x९००	२
		सोफा- २/३ जना बस्ने	३
		सहायक टेबुल १ -४५०x४००	१
		सहायक टेबुल २ -९०० x४००	१
		दराज-५२५x१२००	१
		कुर्सी १-६००x५४०	१
		कुर्सी २-३९०x५०५	२
		फाइल दराज-१३००x३७५	१
२.	बैठक कक्ष	बैठक टेबुल-९७५x१५७५	१
		कुर्सी-४००x५००	६
३.	प्रतीक्षालय	काम गर्ने टेबुल-२५००x६००	१
		कुर्सी १-५५०x५५०	१
		कुर्सी २-४००x५००	२
		सोफा- २/३ जना बस्ने	२
		सहायक टेबुल १ -४५०x४००	१
		सहायक टेबुल २ -९००x४००	१
		दराज-४५०x९००	१

ड) उपसचिव (रा.प. द्वितीय श्रेणी) वा अधिकृत (रा.प. तृतीय) श्रेणी को आयोजना प्रमुख/ कार्यालय प्रमुखको कार्यकक्ष



चित्र १५: उपसचिव (रा.प. द्वितीय श्रेणी) वा अधिकृत (रा.प. तृतीय) श्रेणी को आयोजना प्रमुख/ कार्यालय प्रमुखको कार्यकक्षको नमूना नक्सा

क्र. सं.	विवरण	क्षेत्रफल (वर्ग मिटर)
१.	कार्यकक्ष	१७
२.	शौचालय	३.५०
३.	बैठक कक्ष	२५
४.	प्रतीक्षालय	१६
	जम्मा क्षेत्रफल	६१.५

फर्निचर विवरण

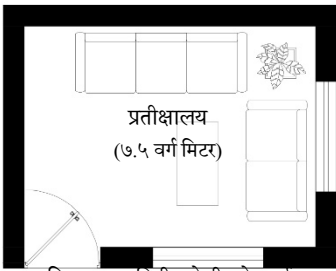
क्र.सं.	विवरण	फर्निचर विवरण (मि. मी x मि.मी.)	संख्या
१.	कार्यकक्ष	काम गर्ने टेबुल-२००० x १०००	१
		कुर्सी १-६००x५४०	१
		कुर्सी २-४५०x४५०	२
		सोफा - २/३ जना बस्ने	१-२
		दराज-४५०x१२००	१
		टी-टेबुल-४५०x९००	१
२.	बैठक कक्ष	सहायक टेबुल २-९००x४००	१
		बैठक टेबुल-३०००x१२००	१
३.	प्रतीक्षालय	कुर्सी १-४५०x४५०	१०
		काम गर्ने टेबुल-१२००x७५०	१
		कुर्सी १-५५०x५५०	१
		कुर्सी २-४५०x४५०	५
		सहायक टेबुल-४५०x४००	१

च) उपसचिव (रा.प. द्वितीय श्रेणी)को कार्यकक्ष



क्र.सं.	विवरण	क्षेत्रफल (वर्ग मिटर)
१.	कार्यकक्ष	९.५
२.	प्रतीक्षालय	७.५
	जम्मा क्षेत्रफल	१७

फर्निचर विवरण

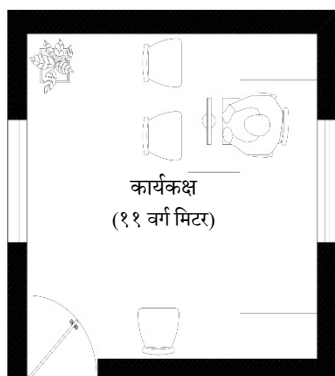


क्र.सं.	विवरण	विवरण (मि. मी x मि.मी)	संख्या
१.	कार्यकक्ष	काम गर्ने टेबुल-१८००x९००	१
		कुर्सी १-६००x५४०	१
		कुर्सी २-३९०x५०५	२
		कुर्सी ३-४००x५००	१
		दराज-४५०x९००	१
२.	प्रतीक्षालय	सोफा - २/३ जना बस्ने	२
		टी-टेबुल-४५०x९००	१

चित्र १६: उपसचिव (रा.प. द्वितीय श्रेणी)को कार्यकक्षको नमूना

नक्सा

छ) अधिकृत (रा.प. तृतीय श्रेणी) को कार्यकक्ष

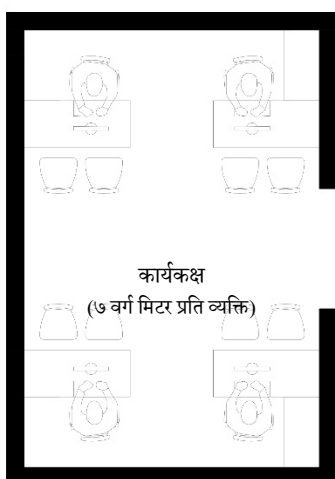


क्र.सं.	विवरण	क्षेत्रफल (वर्ग मिटर)	कैफियत
१.	कार्यकक्ष	११	१ जना कर्मचारीको लागि (कार्यालय प्रमुख भन्दा एक श्रेणी तलका कर्मचारी वा शाखा प्रमुख को हकमा)
२.	कार्यकक्ष	७ प्रति व्यक्ति	१ भन्दा बढी कर्मचारी संयुक्त रूपमा बस्नको लागि (अन्य कर्मचारीको हकमा)

फर्निचर विवरण (१ जना कर्मचारीको लागि)

चित्र १७: अधिकृत (रा.प. तृतीय श्रेणी) को एकल कार्यकक्षको

नमूना नक्सा



क्र.सं.	विवरण	विवरण (मि. मी x मि.मी)	संख्या
१	कार्यकक्ष	काम गर्ने टेबुल-१५००x७५०	१
		कुर्सी १-६००x५४०	१
		कुर्सी २-४५०x४५०	२
		सोफा- १/२/३ जना बस्ने	१
		दराज-४५०x१२००	१

चित्र १८ : अधिकृत (रा.प. तृतीय श्रेणी) को संयुक्त कार्यकक्षको

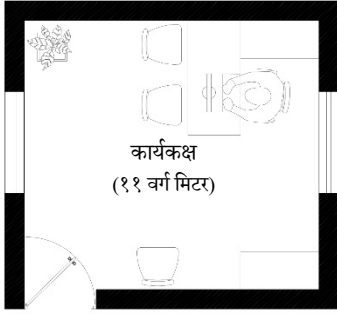
नमूना नक्सा

फर्निचर विवरण (१ भन्दा बढी कर्मचारी संयुक्त रूपमा बस्नको लागि)

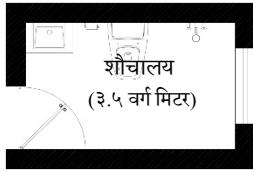
क्र.सं.	विवरण	विवरण (मि. मी x मि.मी)	संख्या
१.	कार्यकक्ष	काम गर्ने टेबुल-१५००x७५०	१(प्रतिव्यक्ति)
		कुर्सी १-६००x४५०	१ (प्रतिव्यक्ति)
		कुर्सी २-४५० x४५०	२ (प्रतिव्यक्ति)
		दराज ४- ४५०x ९००	१ (प्रतिव्यक्ति)

साथै, एउटै कोठामा एक भन्दा बढी कर्मचारी रहने हकमा आवश्यकता अनुसार १५% देखि ३०% सहकार्यात्मक स्थान (Collaborative Space) दिनुपर्नेछ र कुल क्षेत्रफलको न्यूनतम ८ % भण्डारण (Storage) प्रयोजनका लागि व्यवस्था गर्नु पर्नेछ वा आवश्यकता अनुसार छुट्टै स्टोरको व्यवस्था गर्न सकिनेछ ।

ज) ना.सु वा सो सरहका कार्यालय प्रमुखको कार्यकक्ष



क्र.सं.	विवरण	क्षेत्रफल (वर्ग मिटर)
१	कार्यकक्ष	११
२	शौचालय	३.५

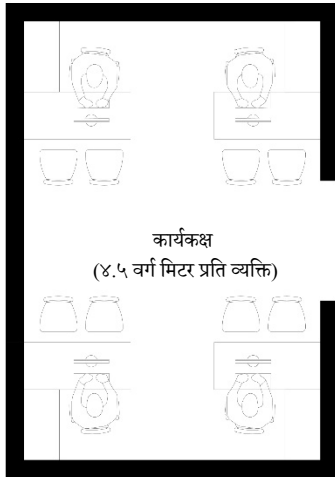


फर्निचर विवरण

क्र.सं.	विवरण	विवरण (मि. मी x मि.मी)	संख्या
१.	कार्यकक्ष	काम गर्ने टेबुल-१५००x७५०	१
		कुर्सी १-६००x५४०	१
		कुर्सी २-४५०x४५०	२
		सोफा -१/२/३ जना बस्ने	१
		दराज-४५०x१२००	१

चित्र १९ : ना.सु वा सो सरहका कार्यालय
प्रमुखको कार्यकक्षको नमूना नक्सा

झ) अन्य कर्मचारीहरू- ना.सु. र खरिदार (रा.प. अनङ्कित) को कार्यकक्ष



क्र.सं.	विवरण	क्षेत्रफल (वर्ग मिटर)	कैफियत
१	कार्यकक्ष	४.५ प्रति व्यक्ति	एउटै कोठामा एक भन्दा बढी कर्मचारी रहने हकमा

क्र.सं.	विवरण	फर्निचर विवरण (मि. मी x मि.मी)	संख्या
१.	कार्यकक्ष	काम गर्ने टेबुल-१२००x७५०	१ (प्रतिव्यक्ति)
		कुर्सी १-६००x४५०	१ (प्रतिव्यक्ति)
		कुर्सी २ -४५०x४५०	२ (प्रतिव्यक्ति)
		दराज ४- ४५०x ९००	०.२५-१ (प्रतिव्यक्ति)

चित्र २० : अन्य कर्मचारीहरू-ना.सु. र खरिदार (रा.प. अनङ्कित)
को कार्यकक्षको नमूना नक्सा

साथै, एउटै कोठामा एक भन्दा बढी कर्मचारी रहने हकमा आवश्यकता अनुसार १५% देखि ३०% सहकार्यात्मक स्थान (Collaborative Space) दिनुपर्नेछ र कुल क्षेत्रफलको न्यूनतम ८ % भण्डारण (Storage) प्रयोजनका लागि व्यवस्था गर्नु पर्नेछ वा आवश्यकता अनुसार छुट्टै स्टोरको व्यवस्था गर्न सकिनेछ ।

ज) कार्यालय सहयोगी/चालकको कार्यकक्ष

क्र.सं.	विवरण	क्षेत्रफल(वर्ग मिटर)	कैफियत
१.	कार्यकक्ष	२(प्रति कर्मचारी)	१ भन्दा बढी कर्मचारी संयुक्त रुपमा बस्नको लागी

क्र.सं.	विवरण	फर्निचर विवरण (मि. मी x मि.मी)	संख्या
१.	कार्यकक्ष	टेबुल	आवश्यकता अनुसार
		कुर्सी -४५०x४५०	आवश्यकता अनुसार

द्रष्टव्यः

- यस अनुसूचीमा उल्लिखित क्षेत्रफल भन्नाले प्रयोगयोग्य खुद क्षेत्रफल अर्थात् कार्पेट एरिया (Carpet Area) लाई जनाउनेछ। पर्खाल, पिलर वा प्यासेजले ओगट्ने क्षेत्रफल यसमा समावेश हुने छैन।
- कार्यप्रकृतिका आधारमा निरन्तर फिल्डमा खटिने वा सधैं कार्यालयमा बस्नुपर्ने कर्मचारीहरूका लागि छुट्टाछुट्टै टेबुलको सट्टा एउटै टेबुल आवश्यकता अनुसार पालैपालो प्रयोग गर्न मिल्ने साझा डेस्क (Shared/Flexible-desk) को अवधारणा लागू गरी कार्यालयको स्थान अनुकूलन गर्नु पर्नेछ।

अनुसूची २: हरित भवन मापदण्ड (Green Building Guidelines)



Government of Nepal
Ministry of Infrastructure Development
Singhadurbar, Kathmandu, Nepal

Physical Infrastructure and Standardized Layout of Government Offices-2083

ANNEX-II

Green Building Guideline of Nepal

Chapter 1

Introduction

- >> Title
 - >> Objectives
 - >> Scopes
 - >> Terminologies
 - >> Green Building: Concept
 - >> Applicability of This Guideline
 - >> Relevant Codes, Regulations, and Legislation of Nepal
-

1

INTRODUCTION

1.1 Title

This document shall be known as the “Green Building Guidelines of Nepal” (GBGN). It serves as a foundational document for the development of National Green Building Code. The guideline establishes a set of regulations that define minimum standards for compliance but is not intended to rate the implementation of green practices in buildings.

1.2 Objectives

The “GBGN” aims to protect Nepalese communities from the impacts of climate change, reduce greenhouse gas (GHG) emissions, and safeguard public health and the environment. To achieve these objectives, the guidelines set standards for both residential and public buildings, addressing aspects such as site selection, planning, design, material quality, construction practices, indoor comfort, and operation and maintenance.

The guidelines promote sustainable building practices that include water conservation, energy efficiency, renewable energy generation, improving indoor environmental quality, and reducing waste. Furthermore, they emphasize enhancing occupant productivity, encouraging efficient resource use and material reuse, and improving environmental and climate impacts of construction. Ultimately, these efforts aim to lower greenhouse gas emissions.

1.3 Scopes

The following are the scopes of the guidelines.

- The Green Building Guidelines (GBGN) provide information, recommendations, and guidance for integrating green and sustainable principles and practices not only during the planning and design stages of new buildings but also throughout the entire lifecycle of the building.
- The GBGN is intended to serve as a foundational document, paving the way for the development of the National Green Building Code. It offers detailed guidance and recommendations for the planning, design, construction, operation and maintenance (O&M), and renovation of green buildings.
- These guidelines should be used in conjunction with other acts, codes, regulations, and standards related to the built environment in Nepal, as well as with relevant environmental considerations.
- The primary audience for these guidelines includes architects, engineers, developers, builders, and other professionals in design teams who are contracted to design and construct buildings. Due to the straightforward structure of the chapters, these guidelines will also serve as an easy reference for building owners, operators, project managers, local authorities, building occupants, and the general public in Nepal.
- Additionally, the GBGN will act as a source of information for the development of the National Green Building Codes when they are implemented.

1.4 Terminologies

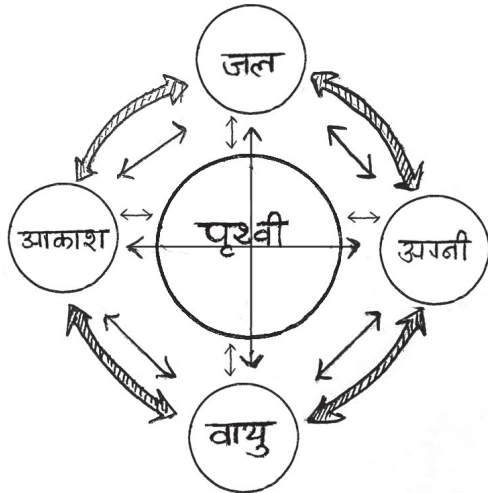
The words, terms, and phrases used in this Guideline shall have the meaning or definition as indicated in the preceding Glossary.

1.5 Green Building: Concept

The concept of green buildings is not new to this region; it has been practiced from time immemorial. The evolution of housing began with the use of natural materials such as stone, wood, and caves, which provided shelter against harsh environmental elements like sun, rain, and wind. According to Vedic philosophy, the methods were developed to maximize the use of pañcamahābhūta or the five

basic elements of nature: Jal (water), Agni (fire), pṛthvī (earth), vāyu (air), and ākāśa (space).

Figure 1: Pañcamahābhūta (Five elements)



Our ancient builders aimed to harmonize these five elements in their building design and construction, leveraging their benefits while minimizing negative impacts. As our ancestors revered these elements and developed methods to utilize them effectively, the underlying principle of green building similarly emphasizes the optimal utilization and conservation of natural resources.

- Green buildings, often referred to as sustainable buildings, are designed to minimize the emission of greenhouse gases, consume less energy, use less water, produce less waste, and provide healthier environments for occupants compared to conventional buildings. The application of the green building concept extends to the planning, design, construction, operation, and eventual decommissioning of a building with minimal resource use. The primary objective is to reduce the negative environmental impacts of buildings through lifecycle planning, efficient resource utilization, and minimizing waste and pollution. The main objectives of the green building are to: Achieve human comfort and well-being.

- Maximize the use of natural energy sources such as sun, wind, biomass, and geothermal energy.
- Minimize environmental impacts.
- Minimize waste generation.
- Optimize energy consumption.
- Optimize resource utilization.
- Conserve water.

Based on the above-mentioned green building concept, UN-Habitat introduced Green Buildings in Nepal with the following five components for promoting sustainable housing in the cities of Nepal in 2013.

1. Green Construction Materials
2. Passive Solar Design
3. Energy Efficiency
4. Water Conservation
5. Waste Management

1.6 Applicability of This Guideline

This document provides guidance for developing green building designs and developments in both urban and rural areas of Nepal in following ways:

- Guides developers, building designers, architects, landscape architects, builders and other professionals while designing green and sustainable private and public buildings.
- Assists planning professionals in local governments with strategic planning and in the preparation of local controls, design guidelines and the assessment of development proposals.
- Informs the community about the principles of green and sustainable design and planning practices for the development of residential places.

1.7 Relevant Codes, Regulations, and Legislation of Nepal

The list of the relevant codes, regulations and legislations of Nepal related to the Guidelines is presented in the Annex.

Chapter 2

Climate and The Site Study

- >> Climatic Zones in Nepal
 - >> Climate Parameters
 - >> Human well-being and comfort
 - >> Principles Of Climatic Design
 - >> Sources for Climate Data
 - >> Climate Analysis
 - >> Site Assessment and Site Analysis
-



2

Climate and the Site Study

Buildings should be designed with a primary emphasis on the local climate to enhance occupant comfort, promote well-being, and reduce resource consumption. Thoughtful design has the potential to decrease greenhouse gas emissions, thereby contributing significantly to climate change mitigation efforts. By accounting for microclimates, which are influenced by factors such as topography and vegetation, designers can effectively leverage natural energy sources, such as sunlight, for heating, lighting, and ventilation. Integrating climate-responsive passive design strategies, such as orientation and natural ventilation, with sustainable design practices can greatly enhance energy efficiency. This approach can lead to energy savings of over 70%, while also supporting environmental sustainability and the health of occupants (Brainbridge & Haggard, 2011)

2.1 Climatic Zones in Nepal

Nepal's diverse topography, ranging from 65 meters to 8,848 meters above sea level, results in a variety of climatic zones. These zones are influenced by factors like altitude, topography, latitude, local

winds, and vegetation. According to the Köppen-Geiger Climate classification, Nepal falls into four climate zones, while the Central Bureau of Statistics (CBS, 2019) categorizes the country into five zones: Tropical, Subtropical, Cool to warm temperate, Alpine & Subalpine, and Tundra & Arctic. For these guidelines, adjustments have been made to the classification of CBS. The term 'tropical' has been omitted as Nepal has no such climate with characteristics of 'Tropical' as defined by Köppen and other systems. Temperate climate has been split into cool temperate and warm temperate. Tundra and arctic climate have also been omitted from the consideration as there is no human settlement in the region.

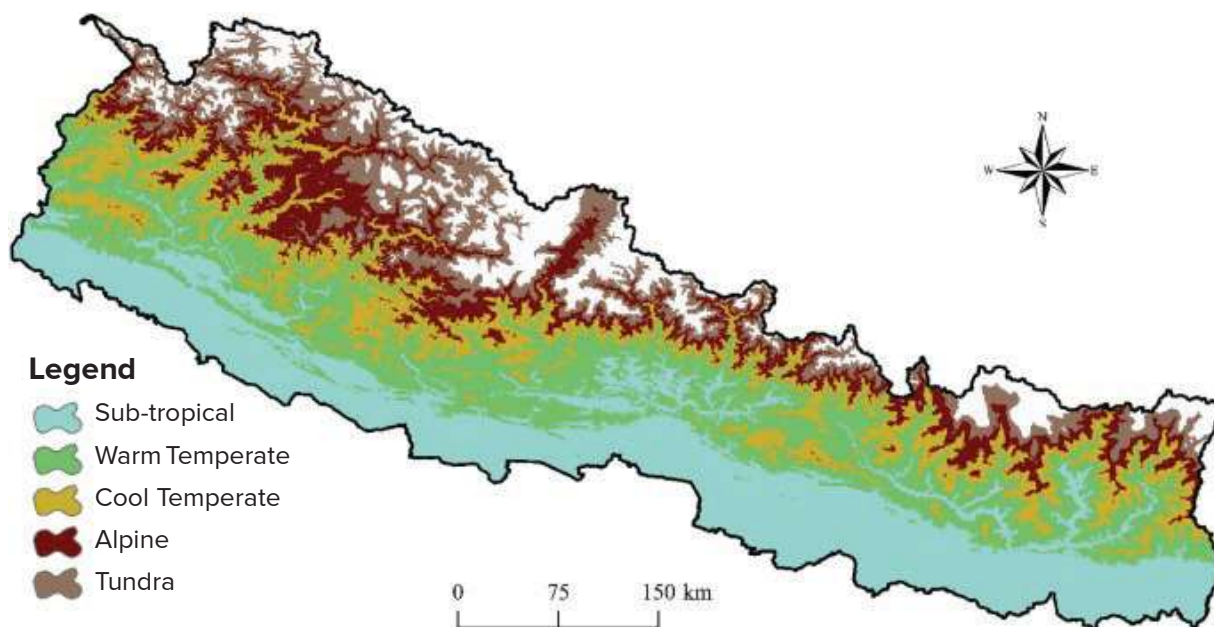
Nepal experiences two main seasons: winter (October to March) and summer (April to September), with the summer season further divided into a hot, dry period (April to mid-June) and a warm, rainy monsoon period (mid-June to September). Understanding these climatic variations is essential for designers to address potential climate-related challenges effectively.

Table 1: Climatic zones in Nepal as per CBS (2019)

Region	Elevation (m)	Climate Zones	Average Annual Precipitation (mm)	Average Annual Temperature (°C)
High Himal	Above 5000	Tundra & Arctic climate	150-200	3-10
High Mountain	3000-5000	Alpine & Subalpine		
Middle Mountain	1000-3000	Cool to warm temperate	275-2300	10-20
Siwalik	500-1000	Sub-tropical	1100-3000	20-25
Terai & Siwalik	Below 500	Tropical		

Table 2 Climate Zones of Nepal adopted for the GBGN

Climatic zone	Sub-tropical	Warm Temperate	Cool temperate	Alpine
Physiographic Region (ICIMOD)	Terai & Siwalik	Hills	Middle Mountain	High Mountain
Global coordinates (Long. Lat.)	28° 48' N, 80° 33' E	27° 42' N, 85° 22' E	28° 48' N, 85° 18' E	28° 45' N, 83° 42' E
Altitude	0-500 m	500-1000 m	1000-3000 m	3000-5000 m
Mean temperature	Winter: 15°C. Summer: >30°C	Winter: 10°C Summer: 24 to 30°C	Winter: <5 °C Summer: 20 °C	Winter: <0°C. Summer: 10 to 15 °C
Koepfen's class	Cwa	Cwb	Dwc	ET
Precipitation	Winter and dry summer:4to 72mm Monsoon – up to 550mm/ month Annual avg.: 100 to 200 mm	Winter and dry summer - 9-106 mm Monsoon – up to 365mm in average. Annual average.: 100 to 200 mm	Annual rainfall: 2,000 mm Annual avg.: 150 mm	Annual average.: 25 to 50 mm in Snow

Figure 2: Map of Nepal with climatic regions

Source: Paudel, et al., 2021

A. Sub-tropical climate

Most of the Terai and Siwalik hills of Nepal with altitudes up to 1200m have a sub-tropical climate dominated by the monsoon (Koeppen: Cwa). This zone is divided into tropical and sub-tropical climates by CBS. It has hot dry, warm humid and cool dry seasons. During winter months, the mean temperature is about 15 °C. Summers have relatively hot days exceeding temperature well above 30 °C. During winter and the dry summer season, the monthly average precipitation is between 4 mm and 72 mm. When monsoon starts in June, the rainfall increases up to 550 mm per month.

B. Warm temperate climate

Most of the Hilly Region (Koeppen: Cwb) at altitudes of 1200-2100m has a warm temperate climate. It experiences a composite climate which changes from hot season to cold season with concentrated rainfall. During summer, outdoor conditions are comfortable with average temperatures between 20 and 24°C. In winter the mean temperature drops to around 10°C. In January, nighttime temperature can reach as low as 2°C. The dry season records monthly precipitation between 9 to 106 mm while during the rainy season, 365 mm is expected on average.

C. Cool Temperate Climate

The middle mountain region of Nepal at an elevation of 2,000 to 2500 m has a cool temperate climate (Koeppen: Dwc). In this zone, summers are significantly cooler than in hills while average winter temperatures are only slightly lower. However, Dhunche is considerably more humid with an annual rainfall of almost 2,000 mm. The lowest precipitation occurs in November and December. Most the highest rainfall is recorded in July and August.

D. Alpine climate

The mountain region in the northern part of Nepal at an altitude of 2500 – 5000m has a dry and cold alpine climate (Koeppen: Dwc). Unlike other zones, this has a very low annual precipitation. During winter, temperature drops below -10°C. In the summer season, the mean maximum temperature rises up to 21 °C. The region has short summer months from May to July. Monthly

monsoon precipitation is only about one-tenth (44-67 mm) compared to the sub-tropical Terai.

Within these climatic zones, a microclimate can vary significantly due to influences like topography, altitude, water bodies, local wind patterns, ground surface conditions, urbanization, and the surrounding environment (natural or built). These elements are essential to consider while selecting a construction site as well as in the design and planning of buildings, as they impact comfort, energy efficiency, and sustainability.

2.2 Climate Parameters

The climatic parameters that directly impact buildings, built environment and human comfort are particularly important for the designers. The main climatic parameters influencing the design, planning and performance of a building are:

- Solar radiation;
- Air temperature;
- Humidity;
- Air Movement;
- Precipitation;

2.2.1 Solar Radiation:

Solar radiation is the primary driver of climate as it influences temperature and consequently other parameters. Passive solar design is one of the tenets within the climate-responsive design that refers to the efficient use of solar energy to achieve comfort in a building. Designers must be aware to use maximum solar energy in cold climate or during the winter season and protect solar radiation in warm climates or during the summer season. Designers should know about the geometry of solar movements in terms of solar angles and solar paths.

Earth tilts at an angle of 23.5 degrees on its axis. It orbits the Sun in 365 days and completes one full rotation on its axis in 24 hours. Due to this axial tilt, rotation and revolution, the angle of sunlight changes continuously which leads to solstice and equinox conditions. This is the main reason for different seasons like summer, autumn, winter and spring on the Earth (Figure 3).

According to solar geometry, the summer solstice is the longest day and shortest night on the 21st of June in the Northern Hemisphere. In Kathmandu, Pokhara, and Dharan (28°N), daylight lasts approximately 14

hours while nighttime lasts about 10 hours. The Sun rises around 5 a.m. and sets around 7 p.m. The Sun's rays strike perpendicular to the line of Cancer (23.5°N) causing a high solar altitude angle in the Northern Hemisphere. It is nearly 84° solar altitude angle at 12 noon in Kathmandu, Dharan and Pokhara. Winter solstice i.e. 21st of December is the shortest day and longest night with nearly 10 hours of day

and 14 hours of night time in Kathmandu Valley. Sun rises nearly 7 a.m. in the morning and sets nearly 5 p.m. in the evening. Sun rays strike perpendicular to the line of Capricorn (23.5°S) causing the lowest solar altitude angle in the Northern Hemisphere which is approximately 34° at noon in Kathmandu, Dharan and Pokhara.

Figure 3: Positions of Solstice and Equinox along with seasonal variations

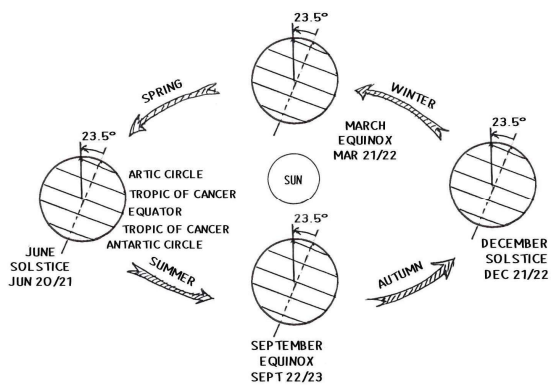


Figure 4a: Solar radiation in solstice conditions on 21st June and 21st December

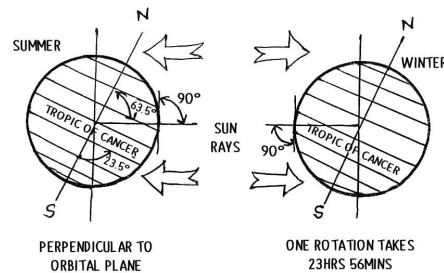


Figure 4b: Incidence of solar radiation in a building in different seasons

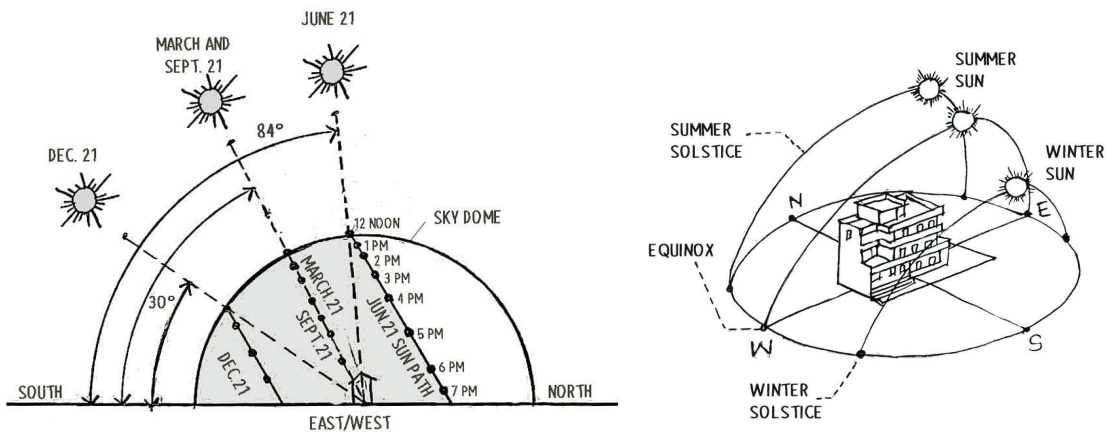
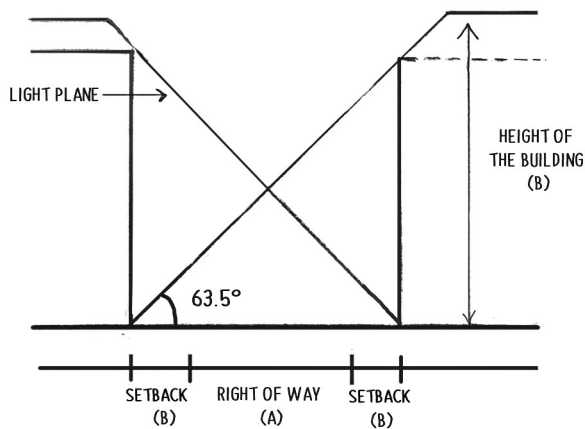
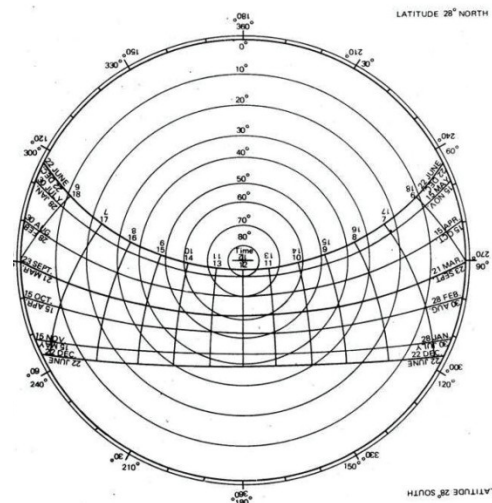


Figure 4c: Diagram of light plane for calculation of building height (H) in front of road.



Equation for the relation is $\tan 63.5^\circ = \frac{H}{a+2b}$
 (Source: Bye-laws of Kathmandu, 2007)

Figure 4d: Sun path diagram



Equinox Conditions occur on 21 March and 23 September when the day and night durations are both 12 hours. In this condition, the Sun rises from an absolute East (90° from North) direction and sets absolute West. So, the sun rises at 6 a.m. and the sun sets at 6 p.m. Sun rays strike perpendicular to the Equator. During these conditions, it is nearly 63.5° solar altitude angle at noon in Kathmandu, Dharan and Pokhara. Kathmandu Valley bye-laws have stated 63.5 as the light plane angle which is used for calculating the maximum allowable height of the building. The bylaws of a maximum building height of 45 feet in mixed old residential sub-zone (core city) areas of Kathmandu are also derived from this rationale. The use of the light plane to calculate building height (H) is illustrated in Figure 4.c.

Solar charts or Sun-path diagrams are used to determine how the sun affects the design context. For instance, once the sun's position (that corresponds to a point on the chart) at a given monthly average day and hour has been found, it is possible to draw an imaginary line, ideally representing the sun's rays, from this point to the building (Figure 4.d.). See Appendix 1 and 2 for details on the usage of this chart.

2.2.2 Air Temperature

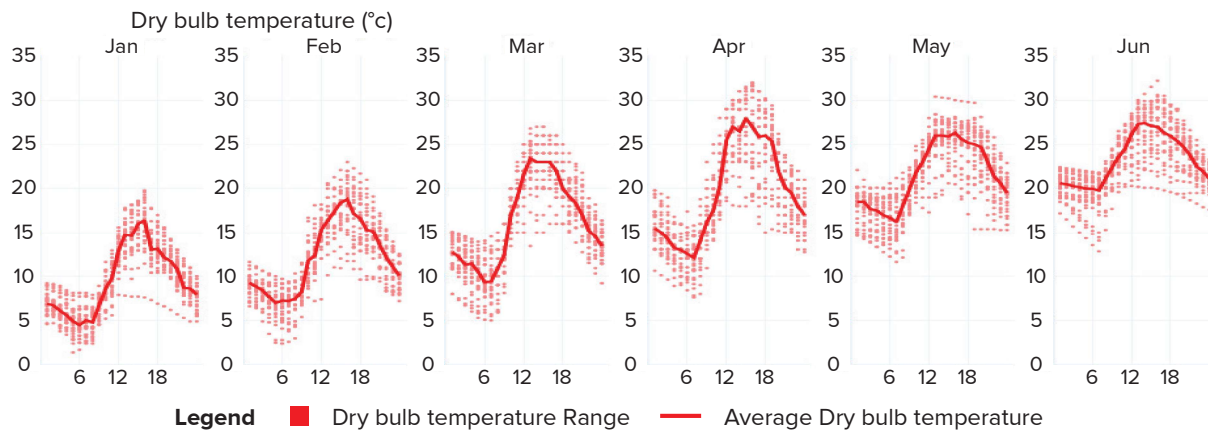
Air temperature is affected by a variety of factors: geographical and topographical context as well as solar radiation and wind. Other factors such as altitude, surface texture, and urbanization

contribute to local temperature variations. Typically, temperature exhibits cyclical patterns, reaching its lowest point just before dawn and peaking in the early afternoon.

- i. Air Temperature Data: Commonly used values include monthly average daily temperatures and monthly mean maximum-minimum differences. This data is gathered at ground level, where the wind speeds are typically low.
- ii. Topographical Factors: Altitude affects air temperature, generally decreasing by about 0.5°C per 100 meters. Cold air pools in valleys and depressions, especially at night, can lead to smog in urban areas in such lowlands.
- iii. Ground Surface Factors: Soil properties like color, texture, and vegetation influence temperature. Bare soil heats quickly, while vegetated areas moderate temperature and increase humidity.
- iv. Site Surroundings: Urban areas absorb more solar radiation due to their structure and materials, creating urban heat islands with temperatures higher than rural surroundings. This effect intensifies with city size and density.

Additionally, terrain slope impacts microclimate. Higher terrain points are windier and suitable for warm climates, while the southern and eastern slopes are sunnier, and western and northern areas are cooler.

Figure 5: Daily temperature record of Kathmandu illustrating the cyclical variation



generated by CBE Clima tool; Available on: <https://clima.cbe.berkeley.edu/>

2.2.3 Relative Humidity

Relative humidity and temperature exhibit an inverse trend during a clear day: when the temperature reaches its peak, humidity hits its lowest point, and vice versa. This is because the amount of water vapor in the air (grams of water per kilogram of dry air) is almost constant (Figure 6). Relative humidity is subject to cyclical fluctuations; it generally increases during the night and during the cold season, when air temperature is at its lowest.

At the local level, relative humidity is affected by various factors, such as vegetation, proximity to water bodies and solar exposure. The presence of vegetation, in particular, due to evapotranspiration, generally increases the relative humidity, so that values recorded in urban areas are typically lower than 5 - 10% compared to those recorded in rural areas. Humidity generally rises near forests, seas, lakes and rivers, due to evaporation.

2.2.4 Wind

Wind is the movement of air masses caused by differences in atmospheric pressure related to land, water and air temperature gradients. The first case refers to regional winds, while the second pertains to local winds. The key parameters which characterize wind are speed, direction and frequency which are represented by a wind rose diagram (See Figure 7).

A schematic representation of the three parameters is given by the wind rose. Presented in a circular format, the wind rose shows the frequency of winds blowing from particular directions. The length of each “spoke” around the circle corresponds to the frequency with which the wind blows from a particular direction over a given period (month, season, year) (Figure 7).

The effect of topography on regional winds is remarkable and can be quantitatively assessed.

Figure 6: Absolute Humidity and Temperature Plot for Kathmandu (RH = 50%)

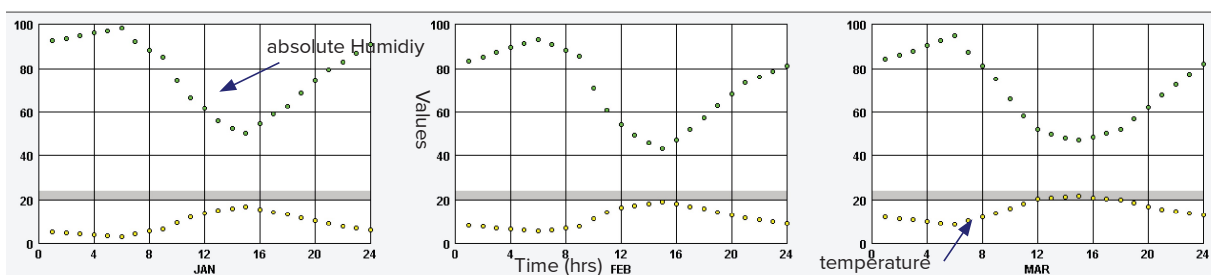
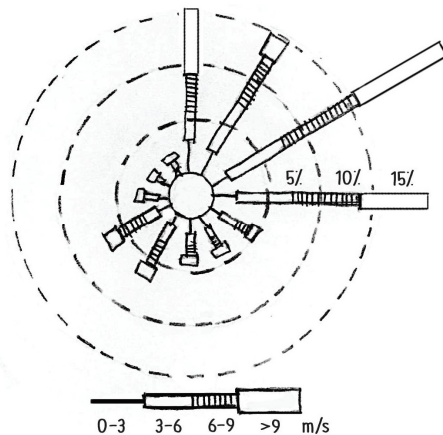


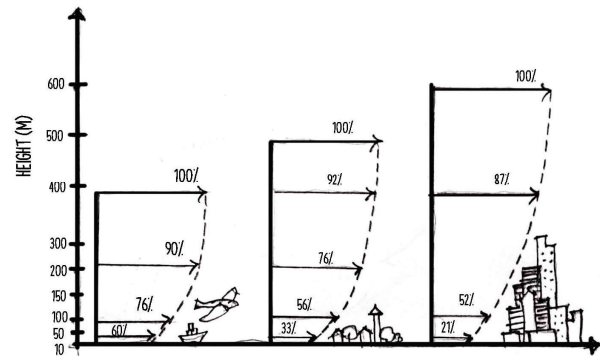
Figure 7: Wind rose

On flat ground, without obstructions, wind speed is influenced by two main parameters: surface roughness of the ground and height. Figure 8 illustrates some examples of wind speed profiles showing that, at the same height, wind velocity is greater in open countryside compared to areas with high building density. Wind is measured by weather stations, situated in a given topographical context.

2.2.5 Precipitation

Precipitation is a collective term used for rain, snow, hail, dew and frost, that is, for all forms of water deposited ('precipitated') from the atmosphere. It is measured using rain gauges, i.e. calibrated receptacles, and expressed in millimetres per time unit (mm/month, mm/day). Annual precipitation refers to the total rainfall and the estimated water equivalent of snowfall for a given year. The maximum recorded rainfall over 24 hours serves as a key indicator for flood prediction. For the surface drainage design (roofs, paved areas, gutters and downpipes) the maximum hourly rainfall intensity (mm/h) should be considered. This factor also helps determine whether rain protection measures are required in the design.

Nepal has a monsoon climate, dominated by an extended wet season starting in June with the arrival of the South-west Summer Monsoon. Rainfall - varies greatly across the country with the general trend of wetter conditions in the east (Taplejung, 1768 m altitude, receives an annual average rainfall of 2024mm) and drier in the west (Baitadi, 1635 m, receives 1037 mm). The average rainfall in Nepal is

Figure 8: Effect of height of structures to the Wind speed

about 1600 mm, with about 80% falling between June and September (above 5500 m this falls as snow). The southern slopes of the Himalaya receive the highest rainfall (3477 mm in Pokhara, 850 m; 5550 mm in Lumle, 1642 m), whilst the trans-Himalaya lands north of the main Himalayan range (Mustang, Dolpa, Manang and Jumla) are in rain shadow with a desert-like barren tundra, barely getting 250 mm of annual rainfall (Jomsom, 2650m, receives 255-295 mm).

2.3 Human well-being and comfort

Human well-being and comfort, a state of physical ease or relaxation and freedom from distress is one of the important considerations in building design. Factors affecting comfort in buildings include personal factors, health and wellbeing, thermal comfort, indoor air quality, visual comfort, noise nuisance and ergonomics. With the relevance of Green Building Guidelines, thermal comfort is largely related to the climatic design hence it is dealt with in this section in detail. The rest of the factors belong to general comfort and hence will be dealt with in detail in chapter 11. (Gut & Ackerknecht, 1993, p. 27)

2.3.1 Thermal comfort

Thermal comfort plays a significant role in occupants' health and productivity, influenced by the body's thermal balance and its adaptations to temperature. A key goal in green building design is to maintain comfortable indoor temperatures while minimizing energy consumption. However, thermal comfort remains subjective, as preferences for warmth or coolness vary among individuals. Architects and

designers generally aim to meet the thermal comfort needs of at least 80% of occupants to achieve an optimal balance.

2.3.1.1 Factors Affecting Thermal Comfort

Thermal comfort is the subjective experience of satisfaction with the thermal environment, influenced by body sensations. The human body must maintain a narrow temperature range for proper functioning. As illustrated by Zhang et al. (2021, cited in Li et al., 2022), skin temperature significantly affects thermal comfort. In extreme cold (<30°C), people feel intense discomfort. When skin temperature nears 30°C, a cool and uncomfortable sensation arises. Thermal comfort is typically achieved between 32°C and 34°C. As skin temperature rises above 34°C, warmth and sweating occur, while temperatures >37°C can lead to extreme discomfort and potential health risks.

The body constantly seeks thermal equilibrium with its environment, regulating heat through radiation, convection, and evaporation, with minimal heat loss through conduction. Thermal comfort is influenced by two key factors:

1. Environmental factors

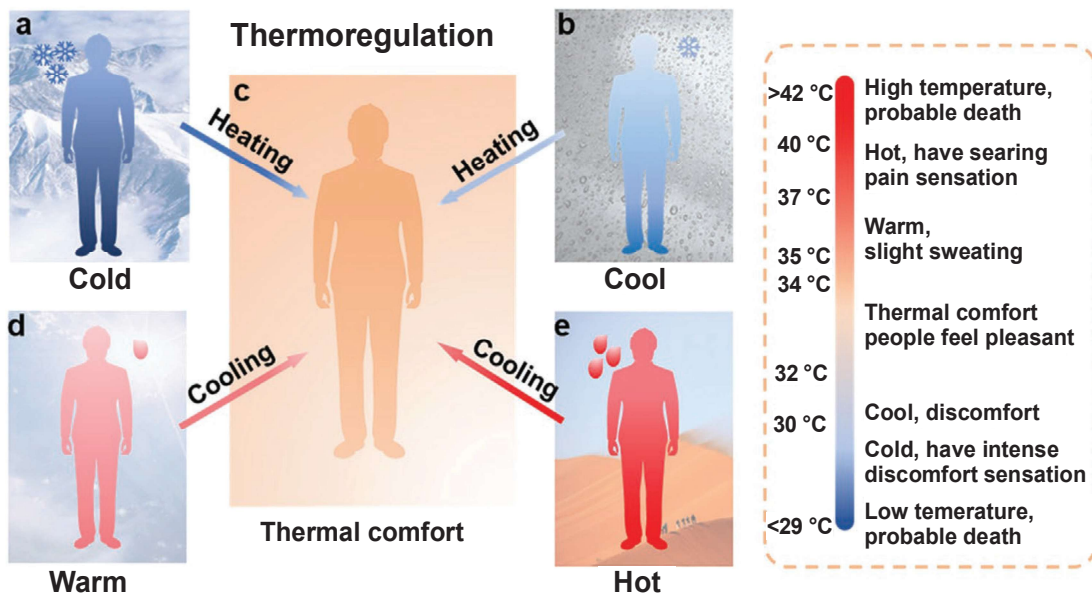
- a. **Dry Bulb temperature (DBT) or Air temperature** - It impacts whether heat loss can occur through evaporation and convection.

- b. **Relative humidity (RH):** Together, RH and DBT of the air around us impact heat loss through evaporation. When RH is high (indicating high moisture in the air), evaporation reduces leading to more sweating. Conversely, when RH is low (indicating low moisture in the air), evaporation increases.
- c. **Mean radiant Temperature (MRT)** - MRT is an important factor in thermal comfort as it influences the amount of heat radiated from the surrounding surfaces to the body, and vice versa. A low MRT can make individuals feel cold even in warm air temperatures, while a high MRT can cause discomfort due to excessive warmth.
- d. **Air speed / Air movement** - Elevated air speed can influence thermal comfort in a couple of ways. When air moves faster across the skin, it enhances heat transfer from the body to the environment through convection. This increased heat loss can create a cooling effect and make individuals feel cooler than they would in the still air. However, if the air speed is too high, it can cause discomfort and make individuals feel cold, especially if the air temperature is already low.

2. Personal factors

- a. **Clothing (Clo) Value** - The Clo value of clothing is important in determining how much heat is lost from the body to the environment, and it can be used to help determine the appropriate

Figure 9: the relationship between human skin temperature and thermal comfort



temperature and humidity levels in a space to achieve optimal thermal comfort. In a cold environment, higher Clo values may help retain body heat and increase comfort. However, in a hot environment, a high Clo value can hinder heat dissipation from the body and lead to discomfort.

- b. **Metabolic rate** - Higher metabolic rates, such as those experienced during physical activity, can increase heat production and cause individuals to feel warmer and less comfortable. Lower metabolic rates, such as those experienced during sedentary activities, may require less heat dissipation, and allow individuals to feel cooler and more comfortable.

Over time, various thermal comfort models and indices have been developed to predict and assess comfort. Recent standards, such as ANSI/ASHRAE Standard 55 (2020), incorporate models like the Heat Balance Model (including Predicted Mean Vote, PMV, and Predicted Percentage Dissatisfied, PPD) and the Adaptive Thermal Comfort Model, which are widely used today. In section 2.6: Climate Analysis provides an overview of tools useful for analyzing climate to support effective thermal comfort design.

2.4 Principles Of Climatic Design

The principles of climatic design, or climate-responsive/passive design, focus on adapting buildings and spaces to local climate conditions to maximize comfort, energy efficiency, and sustainability. These principles rely primarily on passive strategies to meet comfort requirements, minimizing or even eliminating the need for artificial energy-consuming systems. When passive measures alone are insufficient, active systems can be used as supplementary solutions that fills any remaining gaps. This approach can lead to significant reductions in operational costs. The key principles include:

2.4.1 Understanding Local Climate

Understanding the local climate including temperature ranges, humidity levels, wind patterns, solar angles, and seasonal variations allows designers to identify climate-related challenges and develop effective strategies to address them. Designers should consider the following steps:

- **Location of the site and climate data** – Determine the site's location within specific physiological and bioclimatic zones to gain insights into general climatic characteristics and parameter values. For accurate climate analysis, gather representative climate data covering at least the last 10-15 years from relevant data banks or agencies (see 2.2.5 and Box 1 for guidance)
- **Climate Analysis:** Analyze and visualize the collected climate data to pinpoint design challenges and opportunities. This analysis informs strategies for energy efficiency, thermal comfort, and passive design. Analysis tools such as the bioclimatic chart, Givoni's Psychrometric Chart, PMV / PPD and Adaptive model can be used for this purpose. Provisions of ASHRAE 55 are based on the PMV (Predicted Mean vote)/ PPD (Predicted Percentage of Dissatisfied) and Adaptive comfort model.

2.4.2 Defining design objectives

Based on the physiological needs, subjective perception of comfort and functional need, design objectives regarding thermal comfort, visual comfort, sound comfort, energy efficiency, water efficiency, safety and indoor environmental quality are defined. Tools such as Olgyay's bioclimatic chart, Givoni's psychrometric chart, and Mahoney table are commonly used for identifying climatic design strategies. (see 2.6 Climate Analysis)

2.4.3 Developing active and passive design strategies

To meet the design objectives of responding to the local climatic conditions, different active and passive design strategies are formulated. The objective would be maximizing the passive means to achieve the design objectives to reduce the reliance on mechanical means. Only the deficits will be fulfilled by the active means. Above mentioned tools can be used to identify the appropriate strategies for the specific climate.

2.5 Sources for Climate Data

Designers should acquire climatic data from authorized agencies such as the Department of Hydrology and Meteorology, the Central Bureau of Statistics, Airports and weather stations (Open Data Nepal, 2024). These data can be downloaded or purchased from the concerned agency. Besides,

climatic data of many locations in Nepal are freely available in online data banks. (see Box 1). If the data is not available for that specific location, data from the nearby location can be used if that is similar in characters complying with the following criteria.

- The geographical distance between the two locations should be ≤ 50 km.
- The difference in the altitude between the two locations should be ≤ 100 m.

The .epw file is commonly used to perform climate analysis. The list of locations for which .epw files are available as per climate zone of Nepal is given in Table 2. If weather files for the location are not available, one may consider whether data files from various available web sources use statistical methods to generate the .epw file for the location.

2.6.1 Olgay's bioclimatic chart

Bioclimatic chart (Figure 10) is a simple tool for analyzing the climate of a particular place. It indicates the zones of human comfort based on dry bulb temperature, relative humidity and wind speed. On the chart, dry bulb temperature is used as the ordinate and relative humidity as the abscissa. Based on the dry bulb temperature and humidity of a place, one can locate a point on the chart. If it lies within the comfort zone, the conditions are comfortable. If a point falls outside this zone, adjustments are needed to ensure comfort.

2.6.2 Givoni's psychrometric chart

Six zones for passive design strategies are identified on Givoni's chart (Figure 11). The interactive tool

Table 3: The places of Nepal with EnergyPlus Weather File (EPW) Format

Tropical	Warm Temperate	Cool Temperate	Alpine
Nepalgunj	Pokhara	Taplejung	Jumla
Siddharthanagar	Kathmandu	Amargadhi	
Dhangadhi	Dipayal	Okhaldhunga	
Biratnagar	Dhankuta		
Simara	Dang		
	Birendranagar		

Box 1: Climate data files

The data files available in STAT, EPW, DDY formats. Climatic variables are mainly temperatures, humidity, solar radiation, wind speed and direction, solar path parameters, precipitation. These weather files of the locations in Nepal as mentioned in Table 3 can be downloaded from the following website:

- Energy Plus Weather Data: <https://energyplus.net/weather/simulation>
- Climate One building: <https://climate.onebuilding.org/default.html>
- CBE Clima tool: <https://clima.cbe.berkeley.edu/>
- Ladybug: <https://www.ladybug.tools/epwmap/>

2.6 Climate Analysis

Available climate data need to be analyzed to get the findings which represent the climatic situations that need to be addressed. This provides the gap for meeting the requirements of comfort level in terms of thermal, visual and sound. This also quantifies the design measures to meet the requirements of energy efficiency, water efficiency, safety and indoor environmental quality. Climate analysis tools are available online which are listed in Box 2. The following three tools are commonly used for identifying climatic design strategies to achieve the above-mentioned objectives:

of Givoni's Psychrometric chart is available in Andrewmarsh.com (see Figure 16) and Climate consultant (see Figure 13).

Three other zones corresponding to different strategies e.g. air-conditioning, humidification and artificial heating are not passive design strategies. So they are not discussed here. Climatic data (outdoor temperature and relative humidity) can be plotted directly onto the chart, and we can check which of the six zones of the chart those conditions fall into. The zones are defined in the Annex -.

Figure 10: Olgay's Bioclimatic Chart

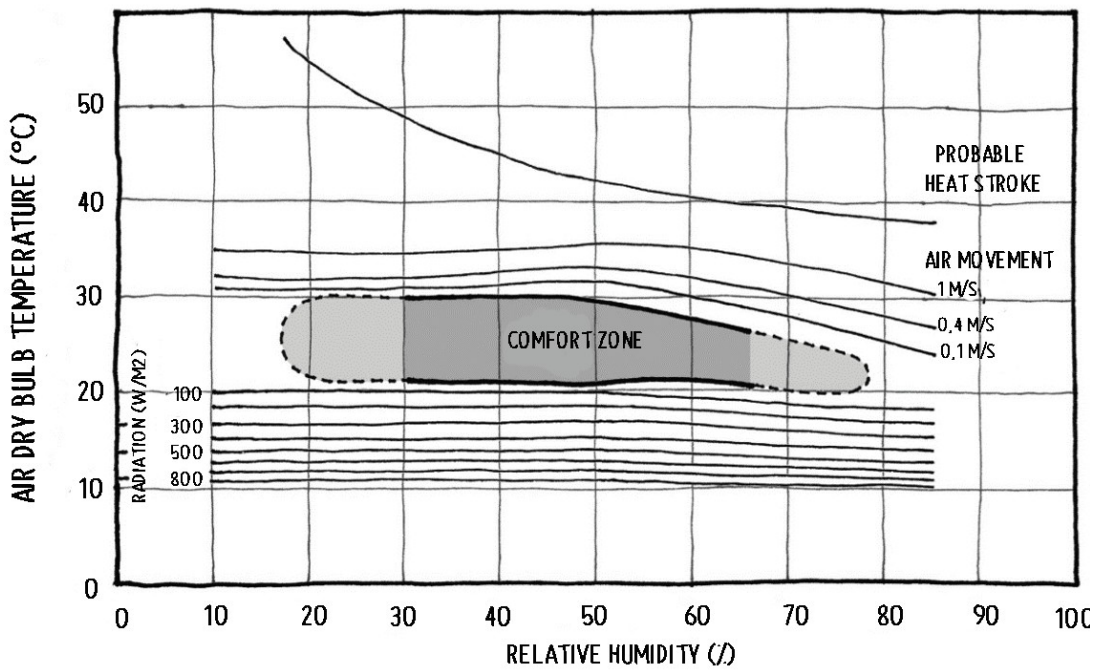


Figure 11: Givoni's Psychrometric Chart with suggested design strategies

Legends

1. Comfort zone;
2. Natural ventilation zone;
3. Evaporative cooling zone;
4. High Thermal mass;
5. High Thermal mass and night ventilation;
6. Passive heating.

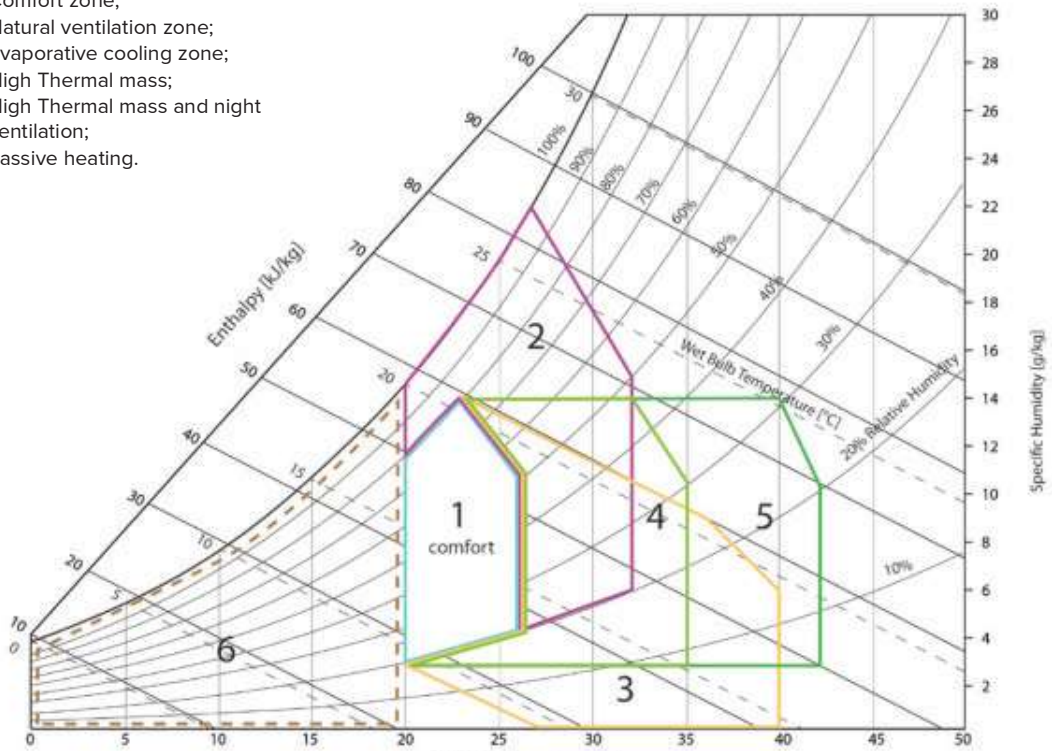
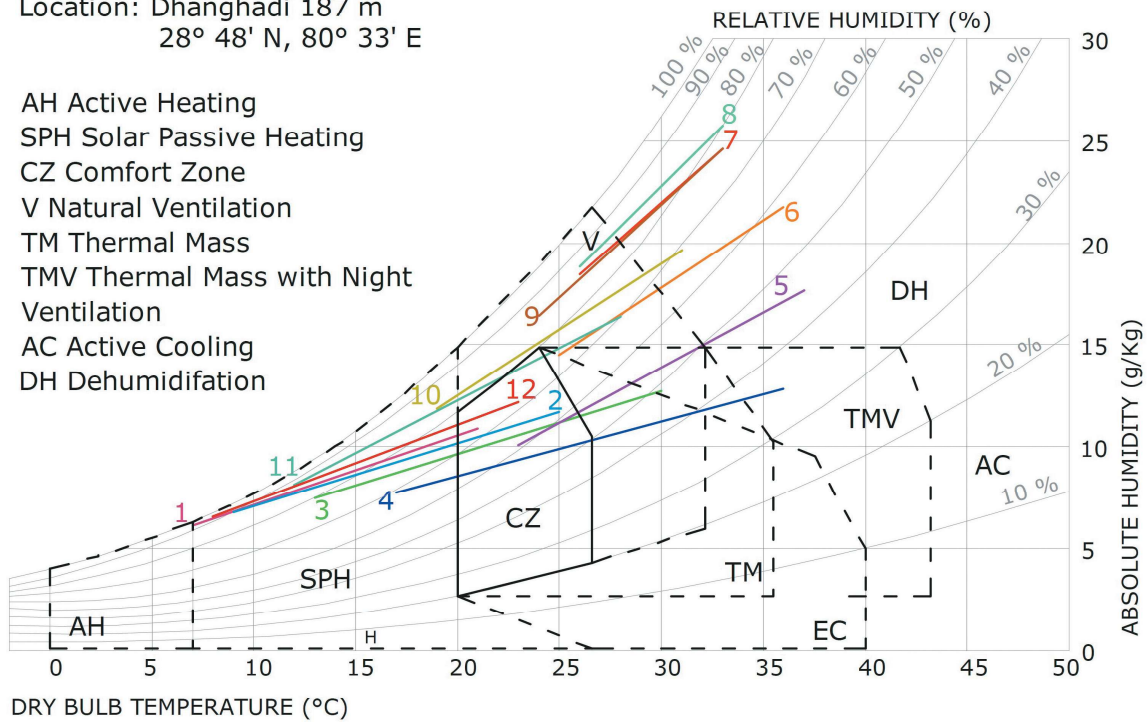


Figure 12: Givoni's bioclimatic chart for four climate zones of Nepal

Subtropical Climate

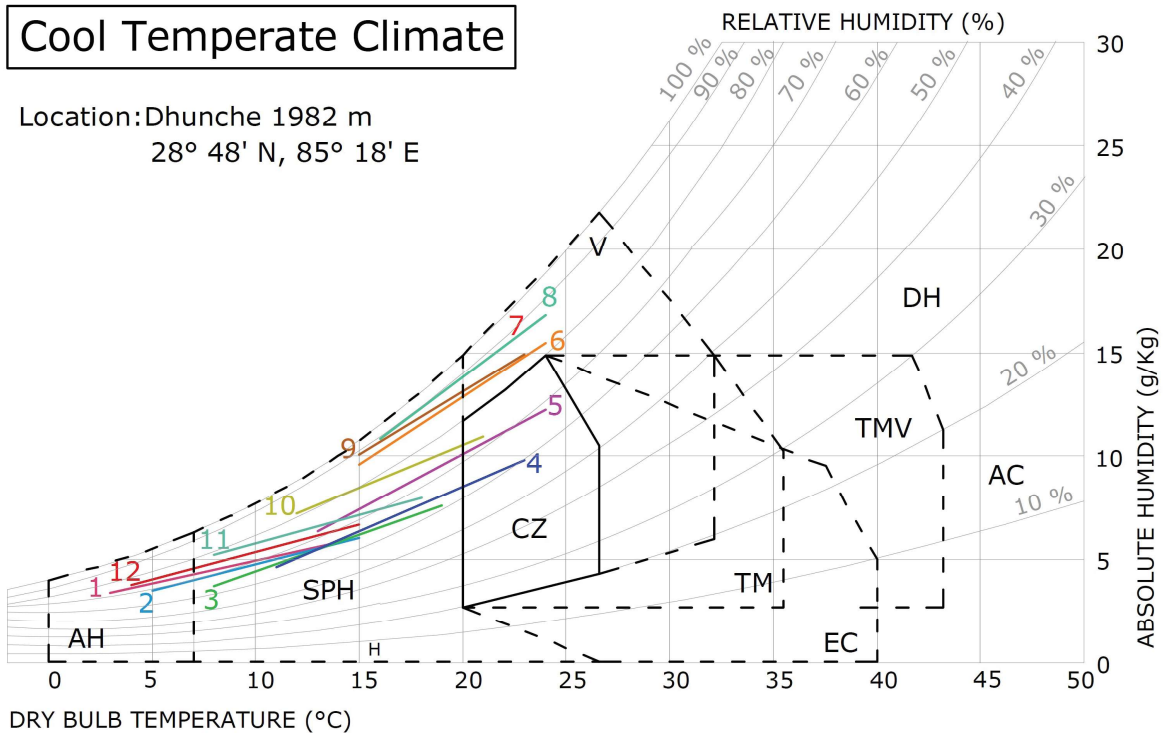
Location: Dhanghadi 187 m
 28° 48' N, 80° 33' E

- AH Active Heating
- SPH Solar Passive Heating
- CZ Comfort Zone
- V Natural Ventilation
- TM Thermal Mass
- TMV Thermal Mass with Night Ventilation
- AC Active Cooling
- DH Dehumidification



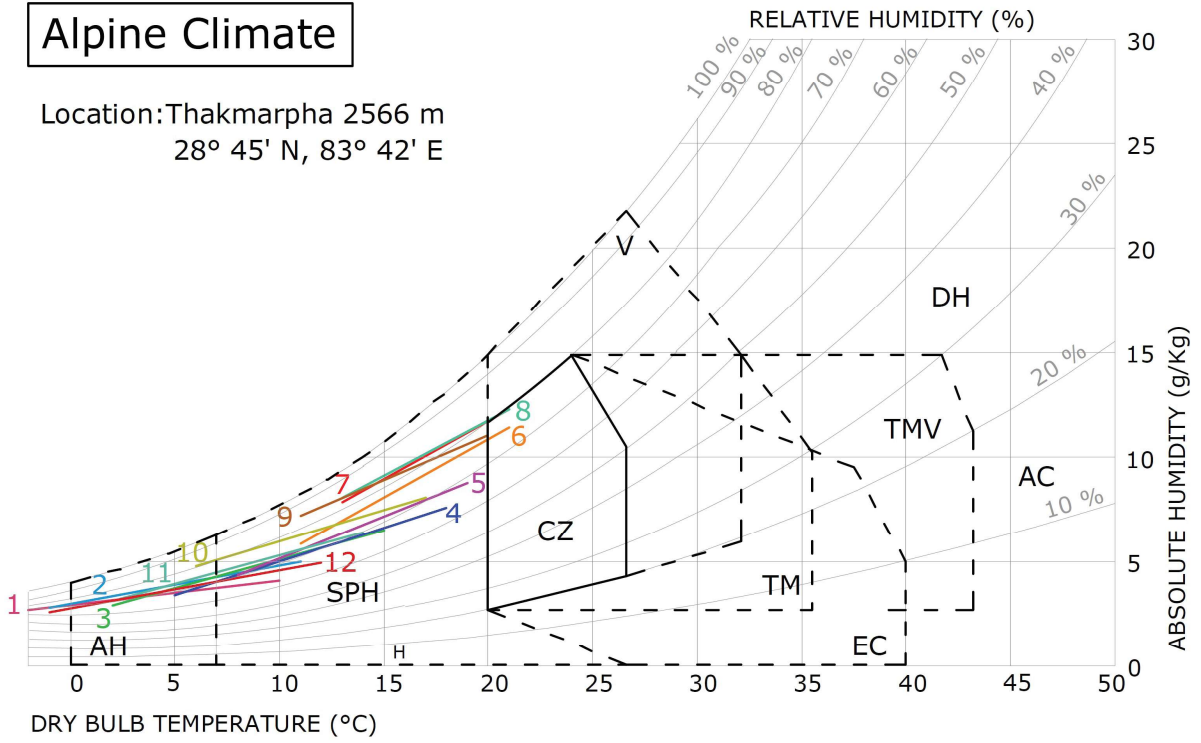
Cool Temperate Climate

Location: Dhunche 1982 m
 28° 48' N, 85° 18' E



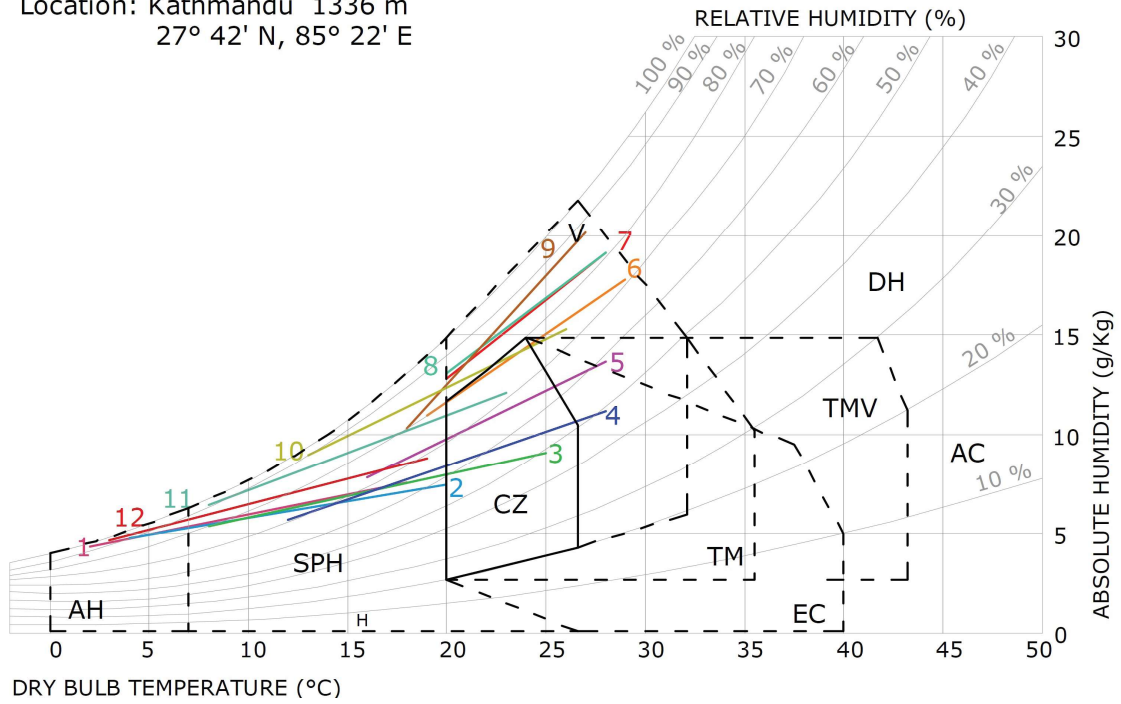
Alpine Climate

Location: Thakmarpha 2566 m
 28° 45' N, 83° 42' E



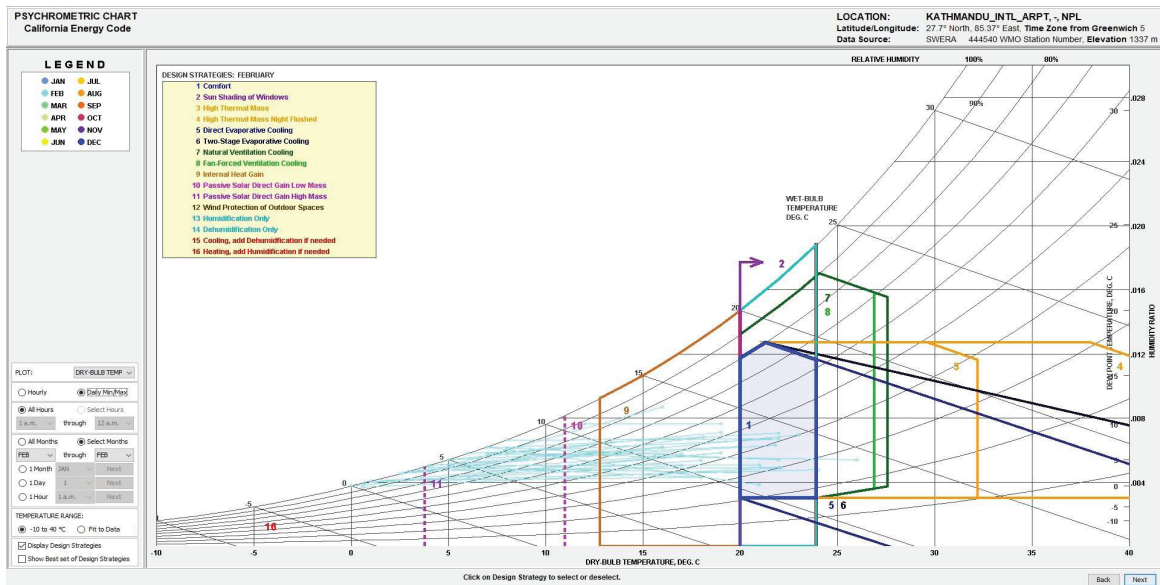
Warm Temperate Climate

Location: Kathmandu 1336 m
 27° 42' N, 85° 22' E



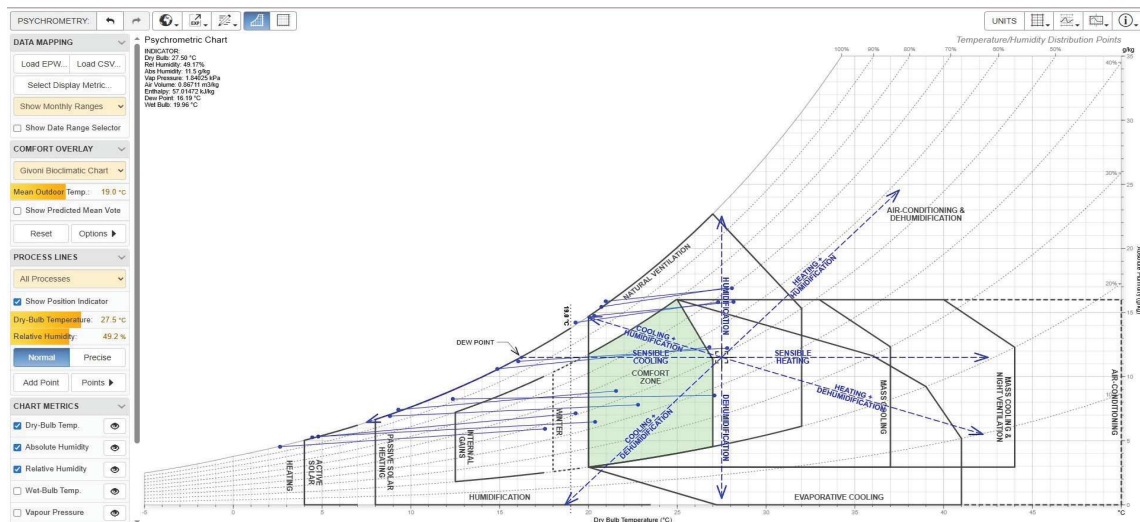
Source: Bodach, et al., 2014

Figure 13: Givoni's Psychrometric Chart for Kathmandu from Climate Consultant.60



Source: <https://www.sbse.org/resources/climate-consultant>

Figure 14: Interactive Psychrometric Chart from Andrewmarsh.com



Box 2: Climate Analysis tools

There are various free online climate analysis tools available which help to analyze and visualize the climate. Some of the widely used tools are:

- **Climate consultant:** A simple-to-use, graphic-based computer program that helps designers to understand their local climate. <https://www.sbse.org/resources/climate-consultant>
- **CBE Clima:** A web-based application built to support climate analysis specifically designed to support the need of architects and engineers.
- **Rhino + Ladybug:** Ladybug Tools is a collection of free computer applications that support environmental design analysis. While the Ladybug plugin is free, Rhino is not a free software.
- **CBE Thermal Comfort Tool:** <https://comfort.cbe.berkeley.edu/>

Source: <https://drajmarsh.bitbucket.io/psychro-chart2d.html>

2.6.3 Mahoney table

The Mahoney table is a set of reference tables that use monthly climate data of temperature, relative humidity and precipitation to calculate indicators for heat and cold stress as well as humid and arid conditions for each month. The combination of these indicators results in simple design recommendations, e.g. “reduce sun exposure”, “compact building layout” or “medium-sized openings”. This is a popular tool in architecture often used as a guide for climate-appropriate design, particularly in composite climates. Mahoney Table mainly consist of four tables:

Table 1: used to record the most essential climatic data

Table 2: used for diagnosis of the climatic data and develop a series of climatic indicators.

Table 3: translates the above into performance specifications or sketch design recommendations.

Table 4: recommends the design of building elements.

Step-by-step method of applying this table for designing is given in Appendix - 3.

2.6.4 PMV/PPD and Adaptive model

ASHRAE 55 is based on the PMV (Predicted Mean vote)/PPD (Predicted Percentage of Dissatisfied) and Adaptive Comfort Model (See Glossary in Appendices). There are several online tools which can be used to check the compliance of the thermal comfort as per different comfort models and indices. Some of the useful tools are presented below:

A. CBE thermal comfort tool

It ensures compliance with ASHRAE 55 standards for the thermal comfort which allows the designer to check with several variables such as operative temperature, air speed, relative humidity, metabolic rate, clothing level. This tool can analyze the thermal comfort using PMV method and Adaptive thermal method.

B. Andrewmarsh.com

This provides several useful software for such analysis. Among them, interactive psychrometric chart 2D from Andrewmarsh.com is relevant for your analysis. This software tool enables the designer to check with different comfort models overlay,

namely Givoni Bioclimatic Chart, Outdoor Work heat Index, ISO 7730:2005 (PMV), ASHRAE 55-2017, EN 15251:2007. Besides, it also allows to change variables of thermal comfort (air speed, cloth level, metabolic level, mean radiant temperature. (See Figure 16)

2.10 Site Assessment and Site Analysis

Site analysis helps identify opportunities or constraints that influence the urban and building design outcome.

1. **Sun Path:** Understanding the sun’s movement during the day and throughout the year allows for a qualitative analysis of the sunlight or shading of a site or part of a building. It is very useful for estimating the effects of the neighboring buildings’ shading or sunscreen needs. The sun’s changing position in the sky throughout the year can be conveniently represented by the sun path diagram. It is represented by a coordinate system (altitude and azimuth) and can be read directly from the diagram at any time of the day and month. This summary of the solar position is useful for design considerations. The most used systems are the polar and the cylindrical sun path diagrams. For detailed calculations please refer to annex.
2. **Prevailing Winds:** Knowledge of the speed and directions of the prevailing winds will facilitate natural ventilation. The main road should be oriented along the prevailing wind direction to promote natural ventilation and help remove dust from buildings. A compromise should be made if the prevailing wind direction conflicts with the sun’s path. A Wind Rose Diagram is used to show wind speed and direction for a particular location and analyses the characteristics of the wind by indicating its strength and frequency over a specified period (month, season and year).
3. **Site Topography:** The existence of rivers, streams, valleys, hills, and mountains may assist or obstruct natural heating and cooling, wind and sun shading. Proper site analysis is required to maximize the use of the existing micro climate.
4. **Vegetation and Existing site features:** They help regulate temperature and reduce dust in urban areas. Trees function as windbreaks and produce oxygen through photosynthesis.

- 5. **Local architectural language and local materials:** Local architectural and local materials (tangible and intangible)
- 6. **Multi-hazard risk assessment:** It is critical to assess the possible multiple disaster risks (e.g. floods, landslides, fire, lighting etc.)

Figure 15: Windrose diagram

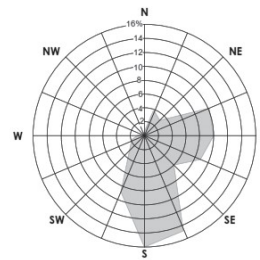
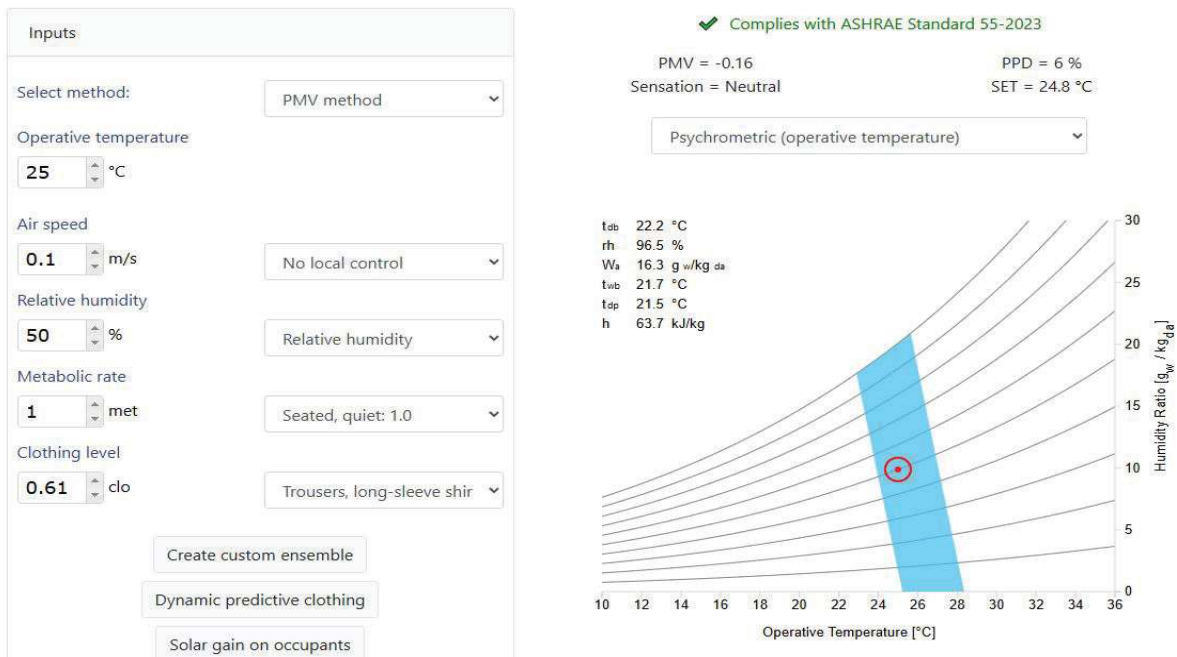
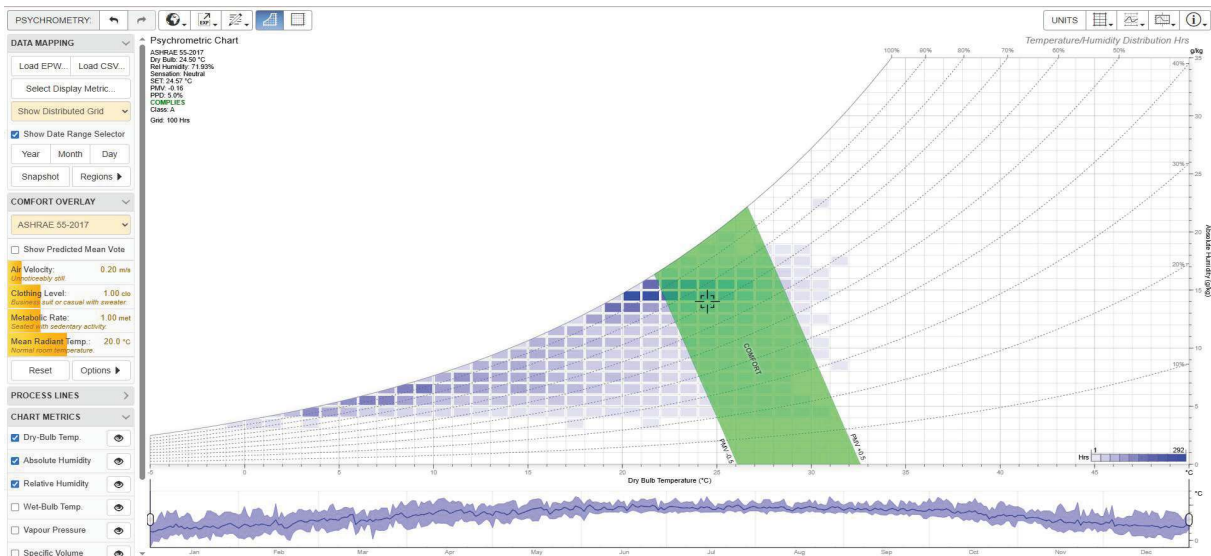


Figure 16: CBE thermal comfort Tool



Source: <https://comfort.cbe.berkeley.edu/>

Figure 17: Interactive Psychrometric Chart from Andrewmarsh.com as per ASHRAE-55 with PMV model.



Chapter 3

Site Planning and Development

- >> General Guidelines for the Sustainable Site Selection
 - >> General Guidelines for Sustainable Site Planning and development
 - >> Guidelines for Site Planning as per Climatic Zone
-



3

Site Planning and Development

Site planning is the process of organizing the physical arrangement of a piece of land to achieve a particular purpose or set of goals efficiently and effectively. It involves the analysis, design, and coordination of various elements such as buildings, infrastructure, landscaping, and natural features within a site to create a functional, aesthetically pleasing, and sustainable environment. Site planning is an important phase in pre-design processes that precedes the subsequent planning, design, construction and operation. Generally, site planning includes the following key components:

1. **Site Selection:** Selection of site for building construction is a crucial step which involves careful consideration of various environmental, social, and economic factors. If site selection is not proper, all the efforts done in other subsequent phase may become useless.
2. **Site Study and Analysis:** When urban planners or designers initiate to design a new building and settlement, they usually look for pre-existing landmarks, such as roads network, slope, rivers etc., and align the new buildings and streets accordingly. Very rarely do they look for the solar path and prevailing winds. These parameters like solar path, prevailing wind, slope orientation etc. are important in order to optimize the human comfort and wellbeing.

The first step of sustainable urban design and site planning is to assess the site's existing conditions, including topography, soil quality, vegetation, hydrology, climate, and surrounding context as mentioned in 2.10.

A specific building site is affected by the following factors: landform, vegetation, water bodies, street width and orientation, open spaces, density, height and built form. An understanding of these factors greatly helps in the preparation of the site layout plan. This provides the basis

for understanding the site which helps planners make informed decisions about the site's development.

3. **Programming:** Identifying the needs and goals of the project or development, including the intended land use, spatial requirements, user needs, and regulatory requirements.
4. **Site Design:** Creating a plan for the layout and organization of structures, circulation paths, open spaces, and other elements within the site. This may involve zoning, building placement, parking areas, pedestrian walkways, and landscaping design. Depending upon the nature of the project, it requires interdisciplinary collaboration among architects, engineers, landscape architects, urban planners, environmental specialists, and other professionals to create successful and sustainable environments. To prepare the sustainable site design the following considerations are necessary:
 - a. **Environmental and Ecological Considerations:** Ensuring that site planning minimizes environmental impact, promotes sustainability, and preserves ecological features such as water bodies, trees, and wildlife habitats etc. and their relationship.
 - b. **Regulatory Compliance:** Adhering to local zoning ordinances, building codes, environmental regulations, and other legal requirements governing land use and development.
 - c. **Stakeholder Engagement:** Involving relevant stakeholders such as property owners, community members, government agencies, and developers in the planning process to gather input, address concerns, and build consensus. This will ensure the social ownership, fitness to the context and minimization of the conflicts.

3.1 General Guidelines for the sustainable site selection

- a) Minimal impact to the environment:** The building site should be selected to minimize the overall impact of the built environment on the natural surroundings. For this, the environmentally sensitive areas should be avoided, and previously developed land should be chosen. EIA or IEE may need to be conducted as per the Environment protection Act (EPA) and Environmental Protection Regulation (EPR) of Nepal.
- b) Location and topography:** The site should be assessed for the solar access, wind pattern, flora and fauna etc. Parameters such as location, slope, aspects of the slope should be noted that determines the microclimatic condition. These parameters directly impact on the human comfort and building energy efficiency which maximize the utilization of daylight, natural ventilation and solar radiation.
- c) Feasibility of the site:** In addition to all the above-mentioned parameters, site should be evaluated for its feasibility. Vulnerable steep slope should be avoided. Even if the slope is reasonably steep, a cost benefit analysis should be done if the site demands high investment in site development. Site without basic amenities (water supply, road access, electricity etc.) should be avoided. In case of unavoidable situation, a master plan needs to be prepared to ensure the availability of those amenities.

3.2 General Guidelines for Sustainable Site Planning and development

With the ultimate aim to minimize environmental impacts, site planning should consider the approaches to protect, restore, and enhance the natural features and environmental quality of the site. The followings are the general guidelines for sustainable site planning:

- 1. Harmony with architectural context:** Design the building in harmony with the context of the site, which minimizes the discordant appearance against the surrounding architectural language.
- 2. Utilize existing structures and site conditions:** The site planning and building design should be in harmony with those of beneficial site

conditions and strive to save, reinforce, amplify, and improve on what is existing.

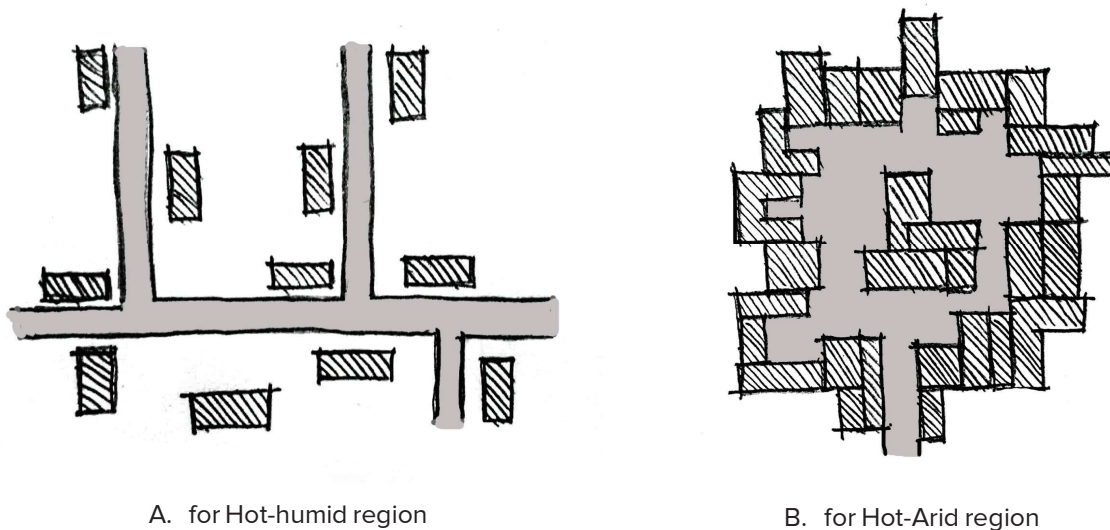
- 3. Minimize disturbance in natural settings:**
 - minimize site clearing to reduce cost
 - Minimize slope disturbance that requires tall retaining walls; instead, the designer should opt for split-level designs.
 - Minimize soil disturbance to prevent erosion.
- 4. Utilize natural site features:** Site layout should be done taking full advantage of natural site features, such as topography, sunlight, shade, and prevailing breezes.
- 5. Ecological consideration:** Conserve ecological resources and develop strategies for ecological enhancement. Also, minimize disturbance to natural habitat enabling wildlife habitat to thrive.
- 6. Prevent soil erosion:** Mitigate erosion to reduce topsoil loss and protect surface water quality.
- 7. Existing and native vegetation:** Preserve existing vegetation as that reduces landscape maintenance costs. Prioritize preserving native vegetation which adds local character to the site. They also eliminate the waiting period for expensive new plantation to mature.
- 8. Minimize Storm water runoff:** This can be done by applying the following techniques:
 - Reduce impervious surfaces, paved surfaces.
 - removing the center of your driveway so that only the tires of your car make contact with the ground.
 - Add plantings, lawns especially in areas where runoff collects. Plants' roots help absorb run offs and filter out pollutants.
- 9. Building Footprint and Open spaces:** Minimize the building footprint within the site; protect and promote open spaces. This should not exceed 50% of the total plot area (30 or 40%). The remaining area should be permeable (green) to ensure rainwater infiltration (natural draining) and avoid the Urban Heat Island (UHI) effect.
- 10. Functional efficiency:** Maximize factors that contribute to the health and productivity of the occupants, such as: thermal comfort, access to fresh air, acoustic privacy, aesthetic views, efficient functional flow, functional outdoor space.

11. **Reduce water and energy demand:** Develop landscape plans to limit water and energy demand while preserving or enhancing the natural environment.
12. **Sustainable parking design considerations** (Refer to chapter 4 for more details)
13. **Urban layout and external spaces** - Urban layout should be designed in response to the conditions of climatic zone. The basic concerns are the effective provision of shading and air movement. The layout and orientation of streets have a significant effect on the microclimate around buildings. The urban form cannot change the regional climate, but can moderate the microclimate and improve the human comfort conditions for the buildings. The influence of the climate on the layout of traditional settlements

around the world is clearly illustrated by the following examples:

- settlements for hot-humid areas are laid out to make maximum use of the prevailing breeze. Buildings are scattered; vegetation is arranged to provide maximum shade without hindering natural ventilation (Figure 18.a);
- settlements for hot-arid climates are characterized by optimal protection against solar radiation by mutual shading, which leads to compact settlements, narrow streets and small squares. They are also shaded by tall vegetation (Figure 18.b);
- settlements for cool areas are generally laid out to make use of solar radiation during the coldest period and for protection from cold winds.

Figure 18: Settlement pattern for different climatic conditions



3.3 Guidelines for Site Planning as per climatic zone

3.3.1 Sub-tropical climate

This region has climate with hot and humid summer where the temperature reaches up to 45°C. The winter temperature ranges from 7°C to 23°C. This region mainly requires building to be cooled for long summer that lasts from late March to September especially during the day time where the outdoor air temperature is more than 30°C. In this type of climatic condition, protection from the sun is the most important strategy during warm seasons while allowing the solar access during the cool season of

the year (December to February). The passive solar techniques should be used properly along with other possible active solar techniques to reduce the heat and maintain thermal comfort in the building. Since most of the warm seasons are humid, natural cross-ventilation should be maintained. The following measures should be considered for sustainable site design in this region:

Site selection and layout

1. **Use Northern space for coolness:** The site should have more open space on the north for courtyards and ventilation. In case of slope

land, an upward slope facing north, north-east or north-west is highly recommended.

2. Use of Outdoor space: In sub-tropical climates, many of the activities associated with indoor spaces while in moderate or cold climates (washing, playing, working etc.) are most often performed outdoors. So, as the area adjoining the building becomes an extension of the indoor space, it must be treated with equal care by the designer.

3. Block planning - A site with detached free-standing building is preferable for better natural ventilation. A sparse settlement pattern is ideal. However, the building performs best when arranged in cluster as each building gets shaded by neighboring buildings. It is preferable for the site to have a longer frontage facing South, South East and South West.

The distance between buildings should be maintained to avoid hampering of natural light. For this region, a minimum distance of 3 m between buildings in urban areas is required to allow wind to flow between them.

4. Prioritizing area in slope terrain: In the case of slope terrain, higher lands should be used for the building activities to ensure good air movement. Besides, North or north western slope and low-lying area are also preferable as they tend to be relatively cooler.

3.3.2 Warm temperate climate

This region has composite climate altering from hot summer to cold winter and monsoon. The monsoon season is generally warm with high humidity where ninety percent of rainfall occurs. The winter season lasts from December to February. The region experiences high solar radiation during summer and low in winter. Therefore, the buildings have to be heated in winter and excess sunlight needs to be cut off during summer season. The building requires cooling mostly from May to September especially during the day time when the temperature is more than 30°C. Similarly, the building needs to be heated mostly from December to February when the temperature falls below 10°C especially at night time. The sun radiation needs to be stored in day time and released at night. The passive solar techniques should be used properly along with other possible active solar techniques to maintain thermal comfort

in the building. (Also see B, pp -9) The following measures should be considered for sustainable site design in this region:

Site selection and layout

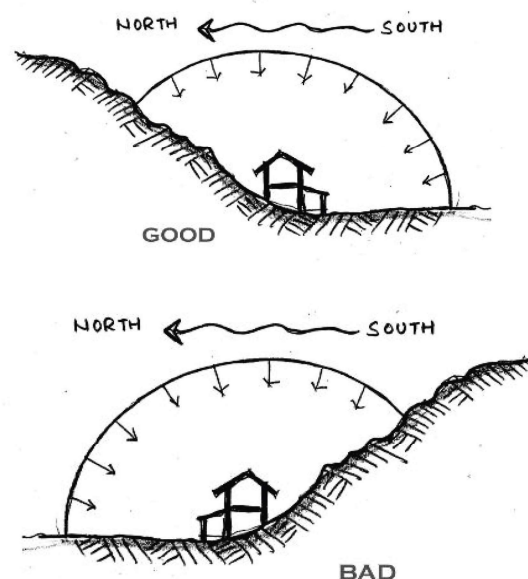
1. **Site with maximum Sun:** Choose a site that allows as much unshaded solar radiation as possible, particularly in the southern direction, to optimize natural heating and day lighting opportunities. Solar geometry should be addressed to maximize the use of sunlight to its fullest extent.

- In case of slope land, south facing upward slope is highly recommended.
- The site adjoining to the street that runs along East-West direction is preferable so that south facing in the plots gets maximum sunlight.

2. **Prevent cold winds**

- **Avoid Winter Breeze:** Prevailing wind direction should be addressed. The streets should be in direction of summer breeze and avoid winter wind.
- **Natural windbreaks:** Select a location with minimal exposure to harsh winds, such as the northern or western sides of hills or slopes to provide natural windbreaks.

Figure 19: Good and Bad site as per aspect of the slope (SONA, 2023)



3. Block planning:

- The site should be planned to provide more space on the south side to allow sunlight to enter. Courtyard planning is also desirable. Therefore, the building should be located towards northern side of the site. Measures (tree plantation, locating other blocks etc.) should be implemented to block east and west sun light or change the wind direction.
- It is preferable that the site have longer face towards South, South East and South West.

3.3.3 Cool temperate climate

Most of the features of the climatic conditions are similar to the warm temperate climate as mentioned in 3.3.2. The difference is only in the range of the temperature. This climate zone has a colder winter that is slightly longer than the warm temperate climate. Hence, design strategies stipulated in 3.3.2 remains same in this zone in terms of site planning development.

3.3.4 Alpine climate

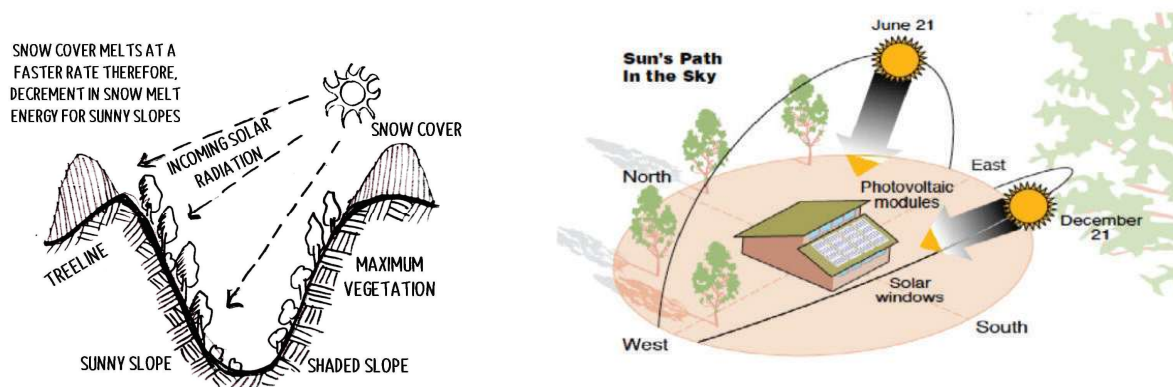
This region experiences extreme weather condition with short summer and long winter that lasts from October to March. Therefore, the buildings have to be heated for long winter especially for night time. The solar radiation must be admitted in the building as much as possible during the day time and store in thermal mass for the heat to release during nights. The passive solar techniques should be used properly along with other possible active solar techniques to maintain thermal comfort in the

building. (Also see D- pp. 9). The following measures should be considered for sustainable site design in this region:

Site selection and layout

- 1. Site with maximum Sun:** Choose a site that allow as much unshaded solar radiation as possible, particularly in the southern direction, to optimize natural heating and day lighting opportunities. Solar geometry should be addressed to maximize the use of sunlight to its fullest extent.
 - In case of slope land, south facing upward slope is highly recommended.
 - The site adjoining to the street that runs along East-West direction is preferable so that south face in the plots gets maximum sunlight.
- 2. Prevent cold winds**
 - **Avoid Winter Breeze:** Prevailing wind direction should be addressed. The streets should be in direction of summer breeze and avoid winter wind.
 - **Natural windbreaks:** Select a location with minimal exposure to harsh winds, such as the northern or western sides of hills or slopes to provide natural windbreaks.
- 3. Compact planning:** The site with compact cluster settlement planning is better to take advantage of solar radiation and prevent from cold breeze. The courtyard layout is also preferable.

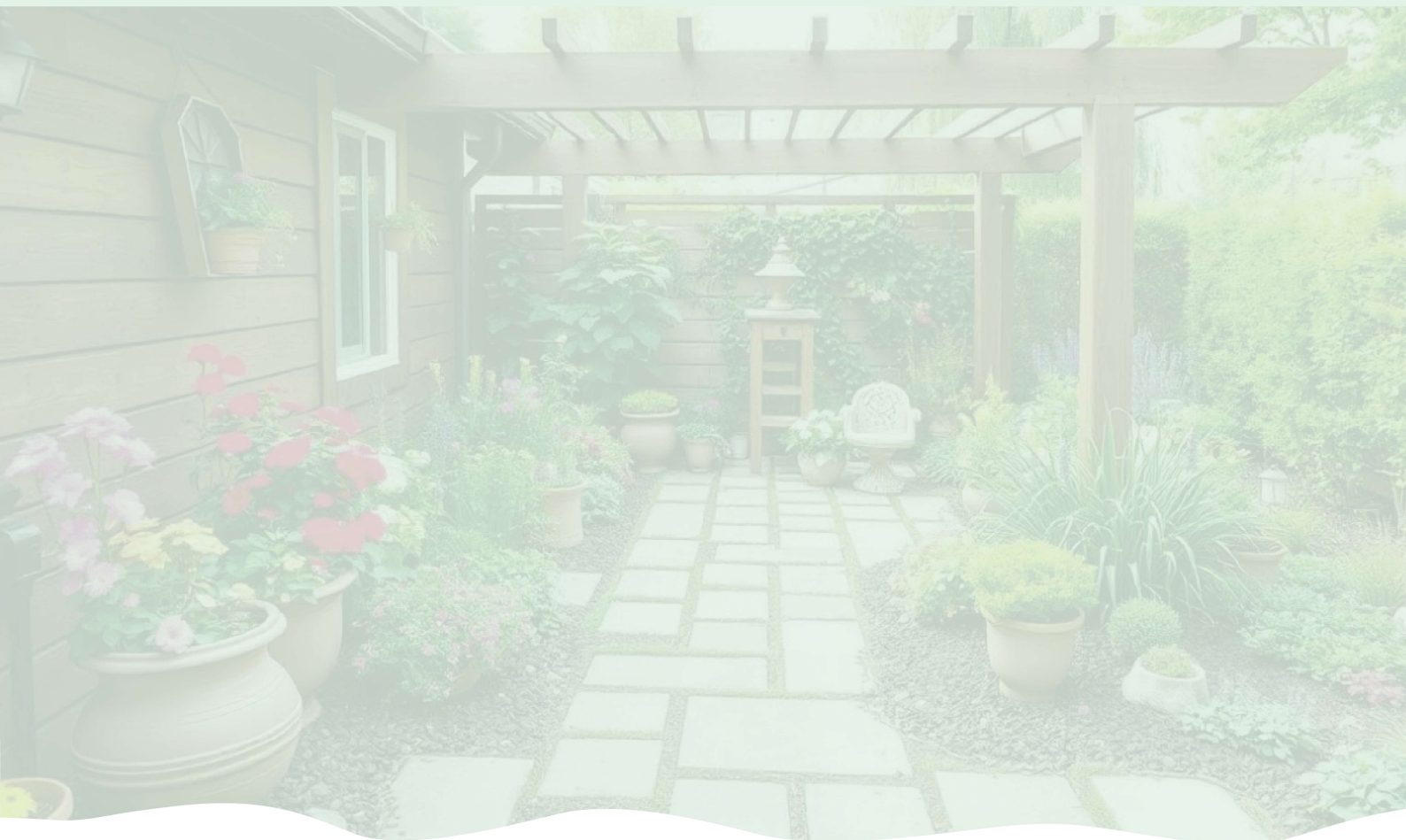
Figure 20: Preferable site slope and solar geometry



Chapter 4

External Development And Landscape

>> Strategic Landscaping



4

External Development and Landscape

4.1 Strategic Landscaping

Strategic landscaping is the intentional planning and design of outdoor spaces to meet goals such as enhancing aesthetics, functionality, sustainability, and practicality. This approach is particularly valuable in urban areas with limited green spaces, where landscaping can help modify the microclimate and mitigate the urban heat island effect. Thoughtfully designed landscapes around buildings can reduce heat absorption and create a cooler environment. Key strategies include:

1. **Maximizing Landscape Area:** Expanding green spaces around the building helps reduce heat absorption, contributing to a cooler environment and promoting biodiversity.
2. **Incorporating Aquascapes or Water Bodies:** Adding water features such as ponds, fountains, or reflecting pools cools surrounding areas through evaporation and enhances the overall aesthetic, further aiding in temperature regulation.

Strategic landscaping not only improves building energy efficiency but also enhances the surrounding environment, providing comfort and sustainability benefits for urban communities.

Measures for sustainable landscaping include the following:

1. **Minimize hard paving:** Amount of hard paving should be reduced as much as possible as it traps the heat around the building creating heat island effect. Additionally, excessive hard paving accelerates stormwater runoff, reducing moisture retention around the site.
2. **Permeable groundcovers:** Use permeable surfaces like permeable pavements or gravel in landscaping designs. This helps reduce

stormwater runoff, allowing water to infiltrate the soil and replenish groundwater.

3. **Erosion Control:** Preventing soil erosion is essential for preserving landscape integrity and water quality. Techniques such as installing erosion control blankets, retaining walls, and stabilizing slopes with vegetation help reduce erosion and sedimentation, protecting waterways from pollution.
4. **Strategic Plantation:** Tree and shrub plantations play an important role in defining wind flow and shades as well as sound barrier to obstruct the noise entering the building. Furthermore, the plants help decrease solar absorption of the hard surfaces thereby reducing heat island effect. So, the area around the building should be maximized for green landscape. There are three main kinds of plants and trees to consider in landscaping.
 - 4.1 **Evergreen trees:** Barrier from harsh wind, pollution such as noise and dust.
 - 4.2 **Deciduous trees:** This type of tree is excellent to provide partly shaded areas and partly sunny. In summer, the trees' leaves shade the building, while in winter, the leaves fall allowing sunlight to access the building. These types of trees should be planted in south and west direction.
5. **Windbreak trees:** Evergreen trees work as windbreak trees; they help prevent fast temperature dropping. So, they should be planted in North West direction to shelter the building from winter wind.
6. **Shrubs and bushes:** They should be planted against the building's exterior walls to provide moisturized fresh breeze in the building.
7. **Water bodies as coolers:** Water bodies act as natural coolers where the moisture from the water body can be used to cool the hot air

around the water body which in turn helps cool nearby buildings. To maximize cooling in hot regions, water bodies should be strategically placed based on a study of wind direction.

8. **Natural Hydrology considerations:** It involves all the issues of water such as quantity, source, movement, flooding, erosion, or waterlogging etc. The following measures are considered for the various objectives:
 - 8.1 **Water Conservation:** This includes using drought-tolerant plants, installing efficient irrigation systems such as drip irrigation or rainwater harvesting systems, and minimizing water runoff through techniques like permeable paving and rain gardens.
 - 8.2 **Natural Drainage Systems:** Mimicking natural drainage patterns helps maintain the site's hydrological balance. Incorporating swales, berms, and contouring the land to direct water flow away from buildings and toward vegetated areas effectively manages runoff while promoting infiltration and groundwater recharge.
9. **Native Plants and Biodiversity:** Utilizing native plants in landscaping helps conserve water and maintain ecological balance. Native plants are adapted to the local climate and soil conditions which require less water, fertilizer, and pesticides. Additionally, diverse plantings support pollinators, wildlife habitat, and overall ecosystem resilience.
10. **Minimum intervention to existing Vegetation and Bio-diversity:** Drastic landscape changes on a site may change its natural parameters. The idea is to minimize the environmental disturbance for conciseness, especially around the construction site. This involves thoughtful planning, using construction methods that don't harm ecosystems, and adding landscaping that helps local plants and animals. By following these guidelines, green buildings help keep ecosystems healthy, support biodiversity, and enhance environmental sustainability.
11. **Don't bulldoze!** –Bulldozing can lead to increased soil erosion. By avoiding excessive clearing, natural vegetation can help stabilize the soil and prevent erosion, contributing to long-term environmental sustainability. Ensure that site grading adheres to accessibility standards, providing barrier-free access to buildings and amenities for all users, including those with mobility challenges. Avoid unnecessary excavation and grading that could disrupt natural habitats and soil stability.
12. **Ensure soil stability:** Disturbing vegetation around a site may lead to soil instability. Therefore, a thorough study of soil type and its bearing capacity is essential to ensure structural integrity and prevent soil erosion.
13. **Climate appropriate plants:** Use of climate appropriate plants for landscaping to minimize watering, pesticide use and maintenance. If a plant does not naturally grow and thrive in the local climate, it should not be planted.
14. **Effective tree management** – Effective tree management in green building involves strategic decisions regarding tree retention, relocation, or replacement. Prioritizing the preservation of existing trees during construction, establishing protection zones, and integrating trees into site design are key practices. This comprehensive approach ensures sustainable tree management, supporting biodiversity, stormwater management, aesthetic appeal and overall environmental health within the built environment.
15. **Green Roofs and Walls:** Integrate green roofs and walls into the building design to enhance insulation, reduce the urban heat island effect, and contribute to overall energy efficiency.
16. **Sustainable Parking Design** – All the strategies should aim to minimize the parking requirements offering several benefits such as reduction of polluted surface water runoff, increased ground water recharge, reduced heat island effect and glare; and opportunities for creating more natural landscapes and pedestrian-friendly environments. Sustainable and green parking design may include the following features to reduce runoff discharged into local water bodies:
 - permeable paving
 - natural drainage landscapes (Swales, rain gardens, and bioengineered planting strips that can improve water quality and reduce runoff)
17. **Storm-Water Management within the Site** - Storm-water runoff can change natural

hydrologic patterns, accelerate stream flows, destroy aquatic habitats, and elevate pollutant concentrations and loadings. Developing a site can significantly alter the hydrologic cycle for the property and surrounding area and may cause the following issues:

- 17.1 stormwater flow over impervious surfaces picking up pollutants along the way and washing them into our rivers and streams.
- 17.2 cause flooding and erosion, destroy habitat and contribute to combined sewer overflows (CSOs).

Measures for sustainable management of storm water include the following:

- i. **Mimic nature** - Storm-water management systems that mimic nature by integrating storm-water into building and site development can reduce the damaging effects of urbanization on rivers and streams.
- ii. **Hydrologic Analysis** - The storm-water management system design shall be based, in part, on a hydrologic analysis of the building site.
- iii. **Not to redirect off-site discharge which harms** - The storm-water management system shall not redirect or concentrate off-site discharge that would cause increased erosion or other drainage related damage to adjoining lots or public property.
- iv. **Directing runoff to natural systems** - Disconnecting the flow from storm sewers and directing runoff to natural systems like landscaped planters, swales and rain gardens

or implementing an eco-roof reduces and filters storm-water runoff.

- v. **Minimizing storm-water runoff** - Implementing following strategies for minimizing storm-water runoff from the project site.

- Limit the number of impervious surfaces in your landscape.
- Use permeable paving surfaces such as bricks, vernacular stone paving (*chapani dhungā*), concrete lattice, permeable concrete blocks to allow water to soak into the ground. Permeable paving is a powerful tool for maintaining and restoring natural hydrological cycles on developed sites by allowing water infiltration rather than concentrating rainwater into runoff. Permeable paving is not ideal for high traffic/high speed areas because it has lower load-bearing capacity than conventional pavement. Nor should it be used on stormwater “hotspots” with high pollutant loads because stormwater cannot be pretreated prior to infiltration.
- Where possible, direct runoff from impervious surfaces across vegetated areas.
- Allow “thick” vegetation or “buffer strips” to grow alongside waterways to filter and slow runoff and soak up pollutants.
- Plant trees, shrubs, and ground cover. They are effective in absorbing up the rainwater that goes up to fourteen times more than a grass lawn does and they do not require fertilizer.

Figure 21a: Recharge Bed

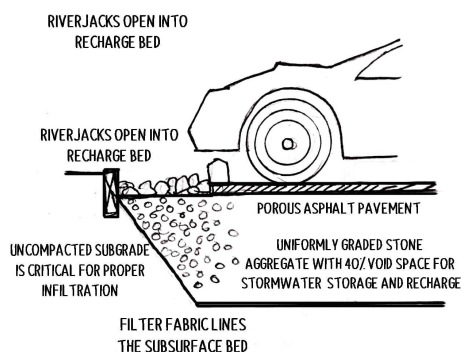


Figure 21b: Swales

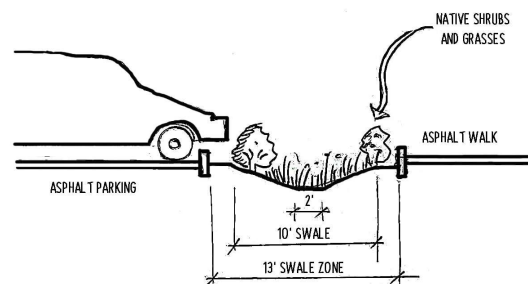


Figure 21c: Detail of recharge bed

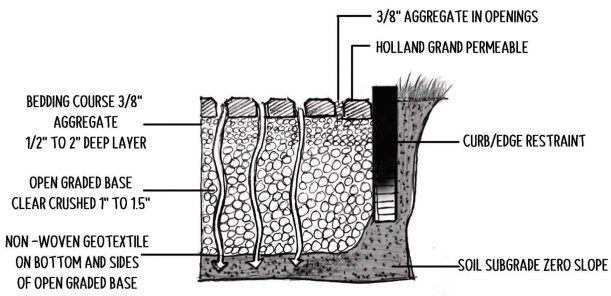


Figure 21d: Impervious Paving

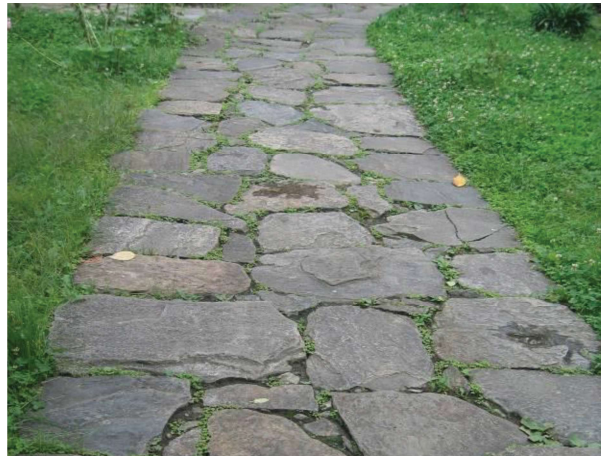


Figure 22a: Deciduous tree during summer and winter

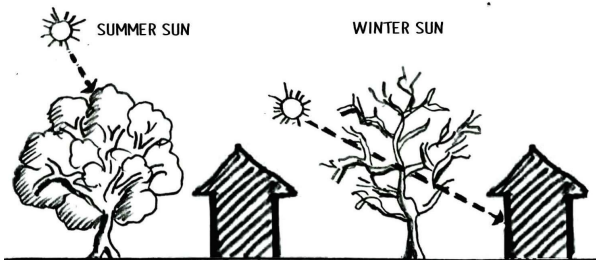


Figure 22b: Wind break trees

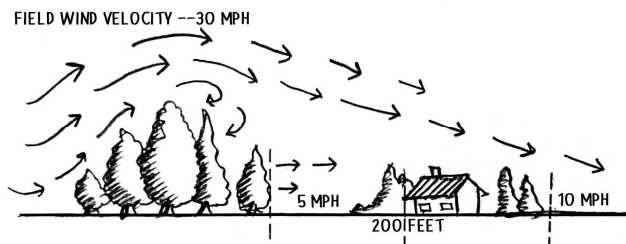


Figure 22c: Illustration of strategic landscape

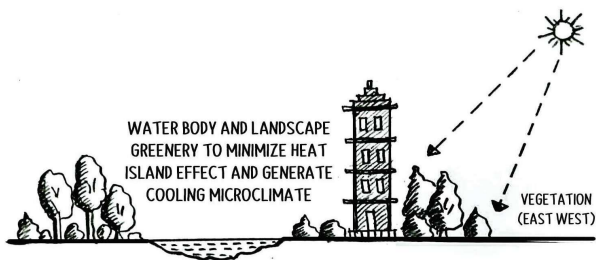
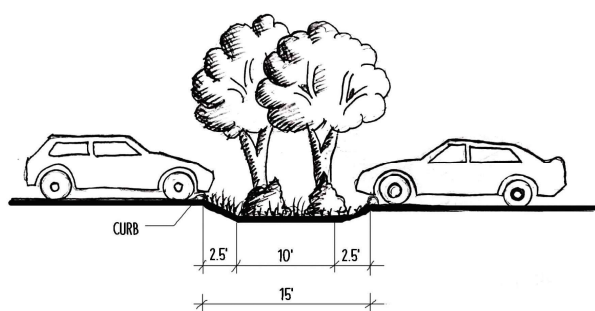


Figure 22d: Sustainable parking design



Chapter 5

Building Form and Orientation

>> Parameter Of Building Form

>> General Guideline for Selecting Appropriate Building Form



5

Building Form and Orientation

Climatic factors affect the form of buildings which is readily observed in the formation of vernacular and traditional buildings. Traditional architectural principles can be studied and the knowledge from them can play an important role in the sustainable design of future buildings. For example, slope roofs of houses in rainy areas, choosing closed and low-opening forms in cold areas, and installing windbreaks in hot and dry or hot and humid areas.

The selection of the appropriate form and orientation for the building is an important initial step in designing sustainable buildings. These factors have important role in optimal use of solar energy and natural air movement. The form of the building determines the creation of shaded areas in hot seasons. Kazanasmaz et al. cited in (Del, et al., 2022) analyzed the thermal performance of the building, which showed that about 50% of energy consumption can be saved devising the building form. The important parameters for building form affecting thermal comfort are building shape, orientation, and window-to-wall ratio (WWR) of the building, density of blocks and height of buildings.

5.1 Parameter Of Building Form

5.1.1 Orientation of Buildings

To define the optimal orientation of a building, the following three factors have to be considered.

A. Sun orientation

Optimal sun orientation minimizes solar radiation during hot periods while allowing sufficient sunlight in cooler months. Figure 23.c shows that the roof receives the most heat because it is exposed to high levels of solar radiation for an extended duration. The west and east façades also receive significant solar radiation due to the low-altitude sun in the late afternoon and early morning, respectively. Therefore, these walls should be considered for shading or having smaller openings.

The term “aspect ratio” refers to the ratio of the longer dimension of an oblong plan to the shorter one. Ideally, the north and south walls should be longer than the east and west walls, with a recommended aspect ratio of about 1.3 to 2.0. The north façade receives the least amount of solar radiation, while the south façade also has reduced exposure due to the sun’s high altitude in the summer months.

In winter, buildings require more solar energy, and the sunlight angle is more inclined. Therefore, vertical surfaces are more effective at capturing solar energy. In contrast, during summer, the sunlight is more vertical, so the roof of the building receives more energy. Preferably, buildings should be oriented with their longer facades facing north-south.

B. Wind Orientation

Cooling through ventilation is typically preferred in building design. Therefore, it is important to orient buildings so that they align with the prevailing breeze. However, this orientation may not always align with the optimal direction for sun exposure. In such cases, a compromise should be reached, placing greater emphasis on the impact of solar radiation. It’s worth noting that the direction of the wind can be influenced to some extent by structural elements.

C. Topographical Orientation

The surface of the surroundings may store and reflect solar radiant heat towards the building, depending on the surface’s angle relative to the solar radiation and on the type of surface (geomorphology). Where this solar heat is not desired, the orientation of the building should be changed or the surface of the surroundings should be covered with greenery that improves the microclimate. The topography may also alter the prevailing wind and provide shade at

certain times of the day. Such elements should also be considered.

5.1.2 Shape of Building

The shape of the building also affects remarkably in thermal performance. Some of the generic shape forms and their attributes are explain below:

1. **Elongated rectangular** – In such form, the orientation of the long axis and short axis is important which is discussed in length in 5.1.1.A.
2. **L, H and C shaped configuration** - L-shaped, H-shaped and U-shaped configurations offer enhanced shading to the courtyard which need to be cautiously planned in response to the solar path.
3. **Courtyard Plan** – Internal courtyards are surrounded by one or two storied building volumes or partly surrounded by high perimeter walls. Attributes of these spaces are:
 - These spaces provide sufficient daylight for various household activities that can be taken place outdoors. At the same time, courtyards constitute a significant source of daylight and natural ventilation to the building interiors.
 - It is evident that the generally large size of the courtyards facilitates air movement which is of primary importance for hot and humid situation.
 - Smaller sized courtyards are particularly effective in the hot dry climate, by providing enhanced protection from intense insolation to both indoor and outdoor spaces.
4. **Semi-open spaces** - Semi-open spaces such as *portico*, rectangular or square-shaped pass-through space, or semi-covered spaces in upper floors. This can be devised in green building for following benefits:
 - Protection against intense insolation through shading during the hot, summer period when the solar altitude angle is high. During the cold, winter period, due to the low solar altitude angle, it allows solar penetration to the building interiors.
 - Constitutes a key environmental feature of a dwellings and offers thermal adaptive opportunities for both hot, summer and cold, winter period.

- Render the shaded and ventilated spaces.
- Outdoor sleeping during night-time hours.
- Moreover, the enclosure of this space on three sides offers protection from cold winds, resulting in a comfortable space for various activities during sunny winter days.
- It may be covered with pergola to get the filtered solar radiation.
- The predominant orientation of such semi open spaces is towards the south or towards the east.
- If it is in entrance area, its protection the front door against rain and snow.
- Semi-covered space on top of flat roofs reduces the heat absorbed by the roof.

5. Single-banked

- Single banked plan forms are elongated room typologies with wide façade, shallow in width (usually 2.5–3 m wide).
 - The large exposed area of such rooms and their linear configuration contributes to excess heat losses and enhanced natural ventilation for fast cooling of the building interiors and removal of the excessive humidity during the summer period
 - It provides better potential for natural daylight penetration and distribution.
6. **Double banked** - It forms a double space room that help creating compact layout. Such layouts minimize the building envelope exposure to the exterior environment and thus reduces heat losses.
 7. **Glass enclosed Atriums Space** – It results in more solar heat gain in summer that increases in discomfort time, while in winter the atrium acts as a solar collector and distributor, contributing to passive heating and decreased heating energy demand.
 8. **High-rise type** – Since they have larger vertical surface relative to roof area, it is good for solar gain in winter time.
 9. **Building Height** – It is characterized by a floor to ceiling height. Larger height is preferred in hot and humid climate whereas lower is desirable in cold climate.

- High-ceilinged spaces reduce the effect of high solar gains through the roof, while the air stratification below the ceiling enables occupants to benefit from lower air temperatures during the hot, summer period. However, it may be cheaper to do the insulation in the roof than high ceiling.

- High ceilings enhance natural cooling ventilation potential which is essential during late afternoon and night-time hours in order to remove the heat stored inside the building mass during daytime.

Figure 23a: Generally, orientation with long axis in east-west direction is preferred

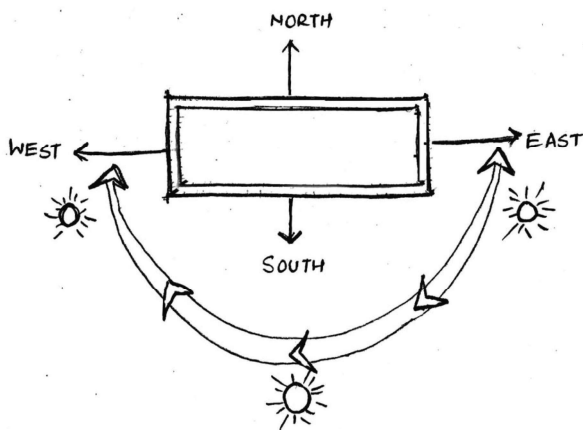


Figure 23b: Topography reflecting solar radiation

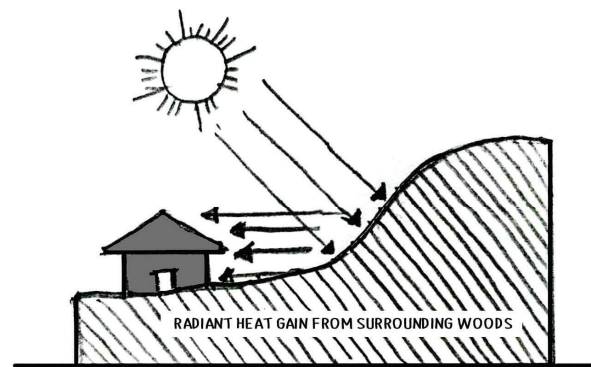


Figure 23c: Solar Radiation Analysis (Summer month - June) in Kathmandu (BEEN, 2024)

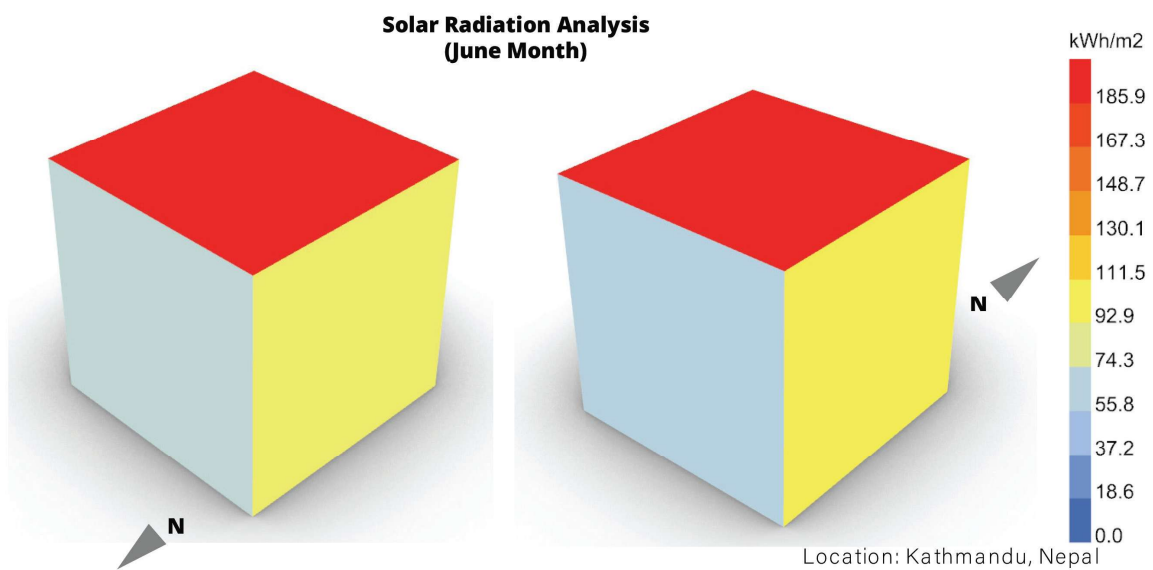


Figure 24a: Building Configuration

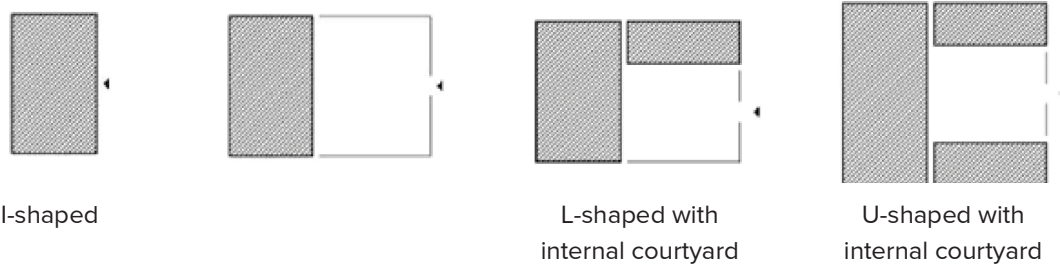


Figure 24b: Storeys of the building

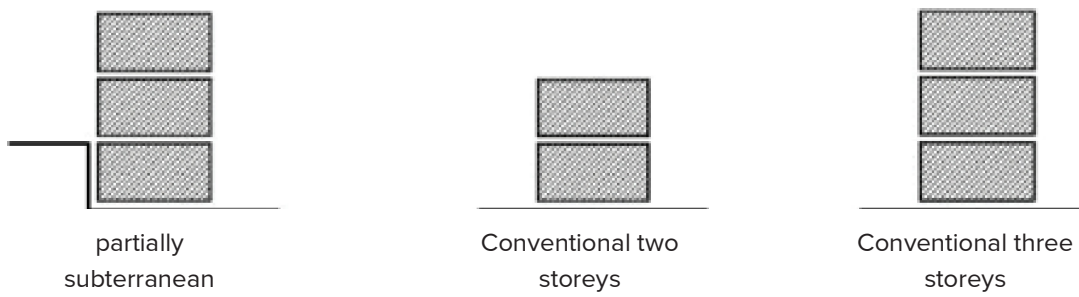


Figure 24c: Single Bank/double bank plan

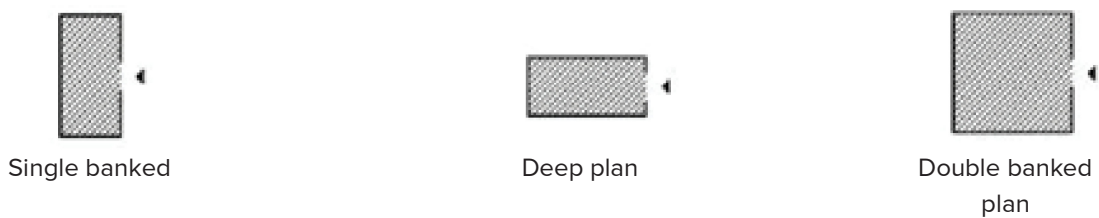


Figure 24d: Semi open spaces

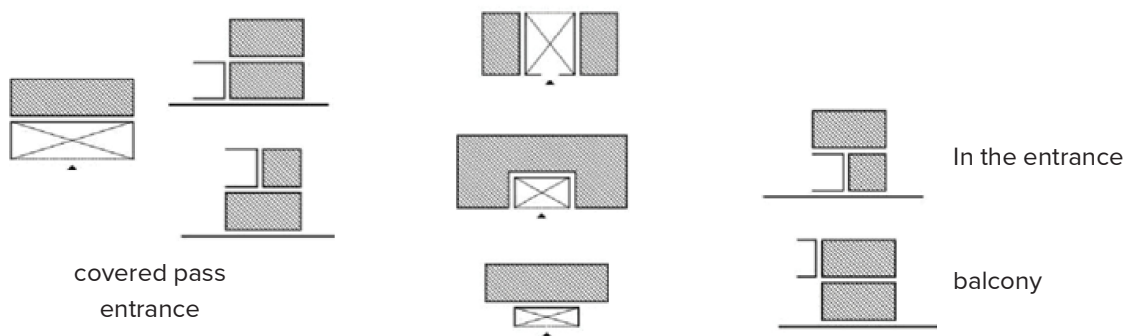


Figure 24e: Courtyard type

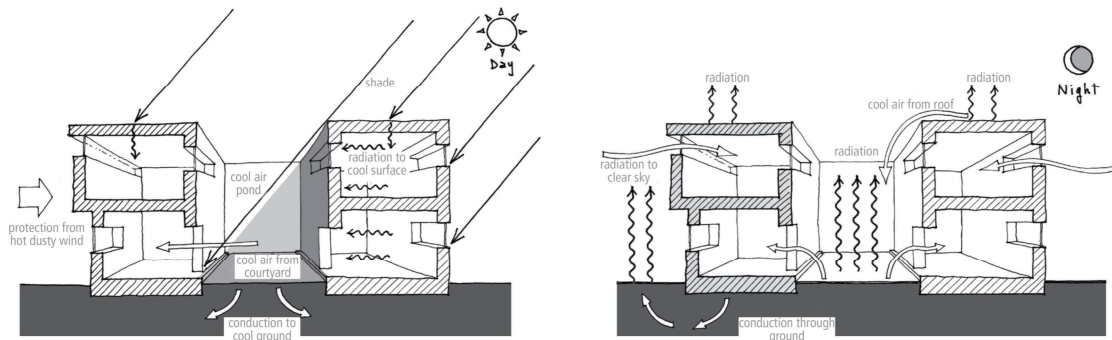
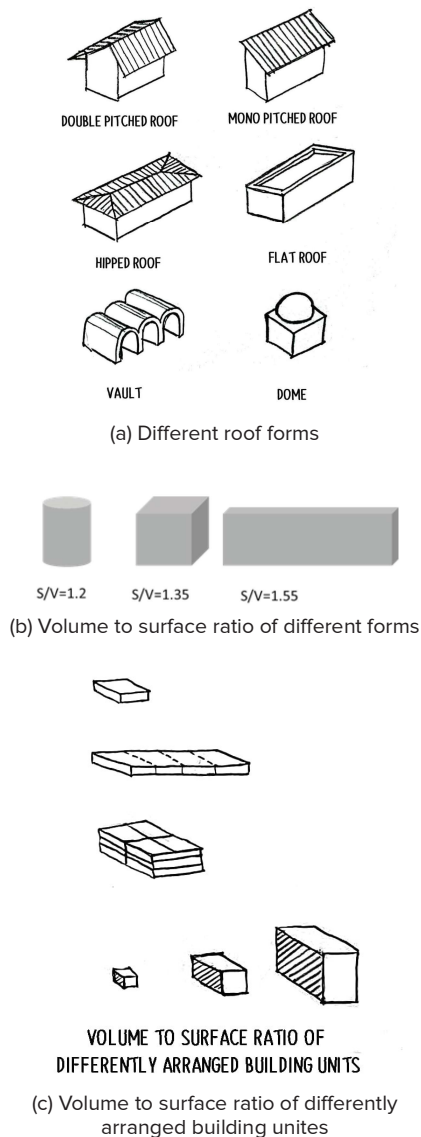


Figure 25: Volume to surface ratio



5.1.3 Roof form

The most important element is the roof. Not only does it protect the building from precipitation, but the strongest thermal impacts (heat loss and heat gain) occur here. The roof is the part of the building which receives most of the solar radiation, and its shading is difficult. Naturally, this applies to single-storied buildings and the top floor of multi-storied buildings only.

The thermal performance of a building is significantly influenced by the roof’s shape and the design of its skin. It is essential to tailor the roof’s configuration to accommodate factors such as precipitation, solar exposure, and usage patterns, whether it be pitched, flat, or vaulted. In hot climates, incorporating a ventilated gap between the sloped roof and the ceiling of the uppermost floor can effectively mitigate overheating.

5.1.4 Surface and Volume Ratio

The functional as well as socio-cultural requirements and particularly the climatic conditions define the form of the buildings. The form of the building can be interpreted in terms of shape and volume, and surface area to volume ratio. The shape could be defined by different geometrical configurations such as elongated rectangular plan, square, circular, polygonal, L-shaped, U-shaped, courtyard or organic shape. The heat exchange between the building and the environment depends greatly on the exposed surfaces. A compact building gains less heat during the daytime and loses less heat at night. Therefore, the ratio of surface to volume is an important factor. A simple model calculation on differently arranged building units illustrates this.

12 building units of 7x7 m width and 3 m height are arranged as individual bungalows, as row houses or as a compact 3-story building. The volume-to-surface ratio changes drastically.

	Volume (V)	Surface area (sA)	(sA) to (V) Ratio
a. as individual bungalows	1764 m ³	1596 m ²	1:1
b. as row houses	1764 m ³	1134 m ²	1:1.6
c. as compact 3-story building	1764 m ³	700 m ²	1:2.5

A similar phenomenon can be observed while comparing large buildings with small buildings of the same shape. This can be demonstrated by comparing cubes of differing volumes:

	Volume (V)	Surface area (sA)	(sA) to (V) Ratio
a. cube 3x3x3m	27 m ³	45 m ²	1:0.6
b. cube 7x7x7m	343 m ³	245 m ²	1:1.4
c. cube 20 x 20 x 20 m	8000 m ³	2000 m ²	1:4.0

In general, where little heat exchange between the interior and the environment is desired, the surface-to-volume factor should be less. The temperature will be close to the average outdoor temperature. Where heat exchange is desired, for instance, to gain from cool nights in warm-humid areas, the surface-to-volume factor should be bigger. This also favors a higher ventilation rate. Particularly in severe climates, it is advisable to present the least surface area for a given volume. From this point of view, the hemisphere is the most efficient shape, but a compact plan is always better than a broken-up and spread-out arrangement.

5.1.5 Space with thermal effects

Space arrangements can be chosen as per the requirement of solar gain. For this, buffer zones can be used to help protect internal spaces from outside weather conditions. These are spaces which will not be regularly occupied and therefore temperatures outside thermal comfort levels are acceptable.

- a. **Functional plan** - When designing the floor plan of a building, apart from the functional arrangements, room connections and privacy requirements, the following aspects should be considered: At what time of the day will the room

Figure 26a: Buffer space shielding strategy

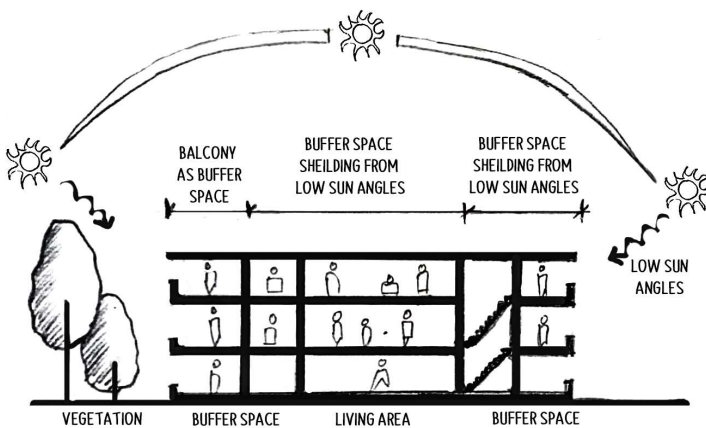


Figure 26b: Use of heavy and light buildings parts as day and night space

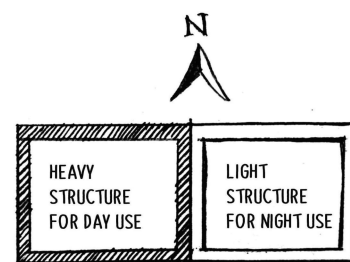
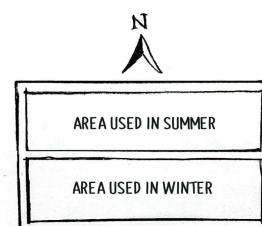


Figure 26c: Orientation of space used in summer and winter



be used? Is the room of prime importance or is it an auxiliary space? Important rooms should be located at places with climatic advantages. For instance, in hot climates, a bedroom is preferably located on the east side where it is relatively cool in the evening, whereas the living room is placed on the northern side. Auxiliary functions should be located on the disadvantaged sides as buffer space, mainly on the western side. Rooms with high internal heat load, such as kitchens, should be detached from the main rooms. Such buffers could include shaded balconies and circulation spaces around buildings.

- b. Separate day and night zone** - Separate day and night zones may be incorporated in the house. The day zone would be a heavy structure retaining the coolness of the night and oriented towards the west. The night zone would be a light structure which cools down quickly after sunset and is oriented towards the east. Similarly, variation in living spaces used in summertime or in wintertime could be provided - a concept which is feasible mainly in temperate zones.
- c. Immediate external space** - In tropical and subtropical regions the outdoor space is actively used. A major part of the social life and the daily routine work takes place there. Depending on the climatic conditions, various forms of courtyards, protected niches and alcoves are common. Such elements should be carefully designed. Trees and other plants are important elements of immediate outdoor spaces. They are inexpensive elements which regulate and improve the climate. At the same time, they add to the attractiveness of this space. (See chapter 4)
- d. Vertical space arrangement** - The ground and the top floor levels create a thermal buffer for the intermediate floor level which accommodates the main living area. The ground floor was used as storage of food products as well as animal shelters. Animals kept in these spaces increase

indoor temperatures of the main living spaces of upper floors during cold or winter periods due to their body heat and breath.

- e. Subterranean spaces** – They provide protection from the cold winter winds and a greater dampening effect of the outdoor temperature extremes due to contact with the earth mass

5.1.6 Other parameters

(See Envelop, opening, Shading is in Chapter 6)

5.2 General Guideline for Selecting Appropriate Building Form

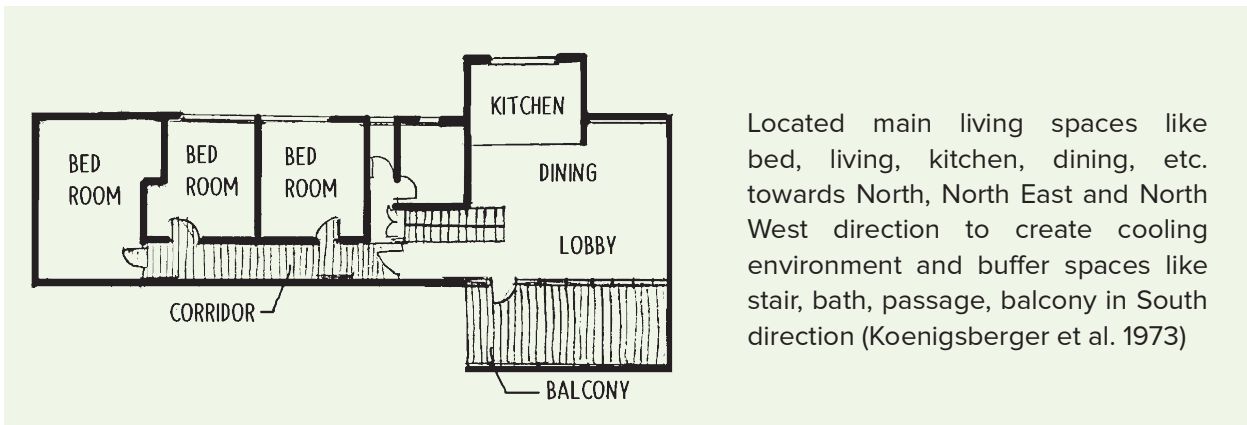
5.2.1 Sub-tropical Climate

Building form

- **Plan form:** An open elongated rectangular plan with a single-row room having both side openings for cross-ventilation is preferable.
- **Roof form:** Roof form may be either slope or flat. It is recommended to use false ceilings and natural hot air ventilation. These ventilation openings should be protected by a net to prevent insects, rodents and other kinds of infestation.
- **Floor height** – It should be as high as possible to escape hot air, ideally more than 9 feet in a residential building.

Internal Space Arrangement

- **Living Spaces away from the Sun:** To optimize comfort and energy efficiency, it is essential to position main living areas and openings in a way that minimizes solar radiation during the summer months. Key spaces such as bedrooms, living rooms, kitchens, and dining areas should ideally be oriented towards the North, North-East, or North-West. This strategic placement helps to create a naturally cooler environment.
- **Buffer space in South:** It is advisable to position buffer areas such as stairs, bathrooms, passages, and balconies in the western and southwestern directions (see Figure 27).

Figure 27: Buffer space

Located main living spaces like bed, living, kitchen, dining, etc. towards North, North East and North West direction to create cooling environment and buffer spaces like stair, bath, passage, balcony in South direction (Koenigsberger et al. 1973)

Building Orientation

- The building should orient with the long axis in east-west direction so that the longer façade face north-south direction. (see Figure 23a)
- The building should orient in northern direction to prevent the heat gain during long hot season.
- The building should be placed in southern side of the site to create open space in north.
- The longer face of the building should face windward direction to allow natural ventilation.
- Buildings can be oriented at an angle of 0° to 30° with respect to the prevailing wind direction.

5.2.2 Warm and Cool Temperate Climate

Building form

- Elongated rectangular plan with singly loaded corridor and proper cross-ventilation is desirable.
- Roof can be either flat or slope but it should have good insulation.
- Windows on two sides of the space should be provided for better light and ventilation.

Internal space arrangement

- The living spaces such as bedroom, living room, office room, kitchen, meeting rooms should be

located in South, South East and South West direction to maximize the benefit of sun light.

- The service core, including lift, staircase, store room, toilets can be located at the north, north east and north west side of the building.
- Ensure that the workstations and frequently occupied areas have access to daylight and outside views promoting occupant well-being and productivity.

Building Orientation

1. **Axis** - The building should orient with the long axis in east-west direction so that the longer façade face north-south direction. The building should orient in southern direction facing 27 degrees southeast to gain proper sunlight but with proper sun shading devices to keep the building cool during summer season.
2. **Minimize wind exposure:** The longer façade of building should not face the windward side.
3. **Gap between blocks:** There should be minimum gap of $2H-3H$ between the buildings in north-south direction where H is the height of the building. The setback between the buildings should be maintained so that light plane is not blocked. (see Figure 28.a)

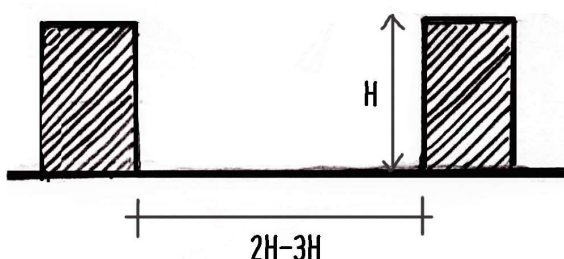
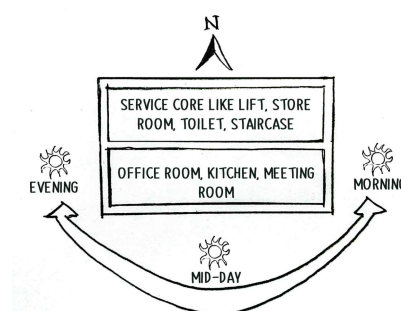
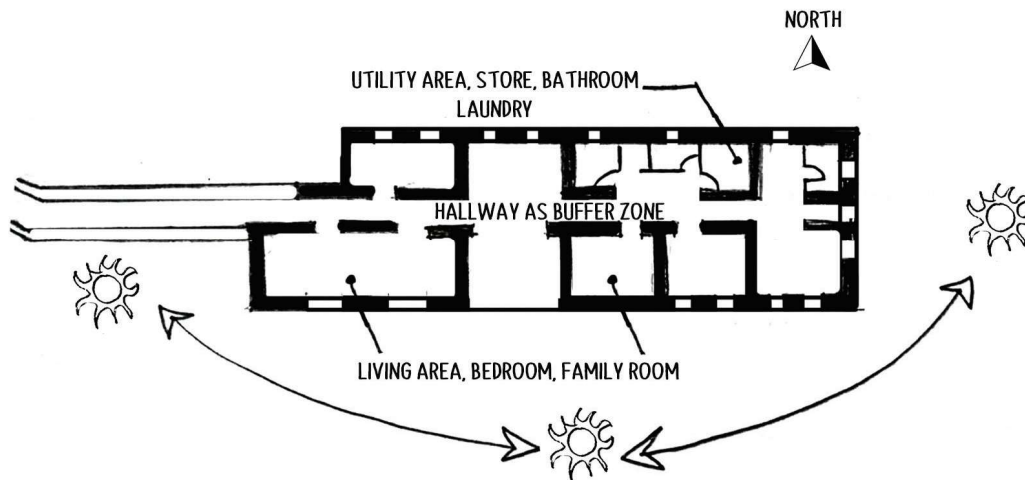
Figure 28a: Distance between blocks**Figure 28b: Internal layout**

Figure 29: Placement of rooms considering solar path

Source: Mato Ghar, Budhanilkantha designed by Ar. Prabal Thapa

5.2.3 Alpine Climate

1. **Compact built form:** The building's surface should be exposed as little as possible to the cold external temperature. Furthermore, the building should retain the heat in the building in winter. For this, compact and clustered planning is preferred to block the cold wind breeze however building blocks should not block the solar radiation to another building.
2. **Floor height:** The floor height should be as minimal as possible. For a residential building, a height of around 2.4m would be optimal.
3. **Internal space arrangement:** Plan the habitable rooms on the southern side and non-habitable rooms on the northern side.
 - The living spaces such as the office rooms, kitchens, and meeting rooms should be located in the South, South East and South West directions to maximize the benefit of sunlight.
 - Ensure that the living space, workstations and frequently occupied areas have access to daylight and outside views, promoting occupant well-being and productivity.
 - The service core, including the lift, staircase, store room, and toilets can be located on the northern side of the building.
4. **Insulation** - The primary considerations for building design in cold regions focus on internal heat retention ensuring thermal comfort within living spaces. To achieve this, buildings must incorporate effective insulation in the exterior walls, use double or triple-glazed windows, and provide insulated roofs. Additionally, it is advisable to include buffer spaces on the northern side to serve as a barrier between the frigid external environment and the warmer southern living areas.
5. **Roof**
 - Roofs can be either flat or slope depending upon the harshness of climate. In areas with heavy snowfall, a slope of the roof not less than 1:12 is recommended.
 - Since the area experiences low rainfall, a sloped roof with a gentle angle or a flat roof designed to collect rainwater would be suitable options.
6. **Building Orientation**
 - **Axis** - The building should orient with the long axis in the east-west direction so that the longer façade faces the north and south directions. It allows orienting living spaces towards the southern side to gain maximum solar heat.
 - **Minimize wind exposure:** The longer façade of the building should not face the windward side.
 - **Gap between blocks:** There should be a minimum gap of 2H-3H between the buildings in the north-south direction where H is height of the building.

Chapter 6

Building Envelope Design

- >> Modes of heat transfer through the building envelope
 - >> Factors influencing heat transfer in building through envelope
 - >> Components of building envelope
 - >> General Guidelines for building envelope design in different climatic zones of Nepal
-

Source: <https://abari.earth/mpp>

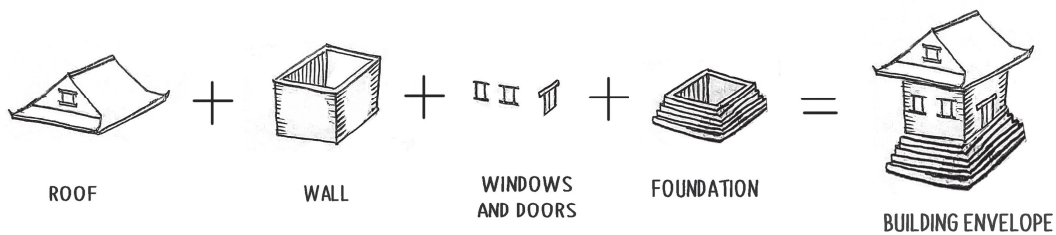
Project: Madan Puraskar Pustakalaya (MPP), Patan Dhaka, Patan

Designers: Nripal Adhikary, Kamal Maharjan, Pranathi, Karit Maharjan

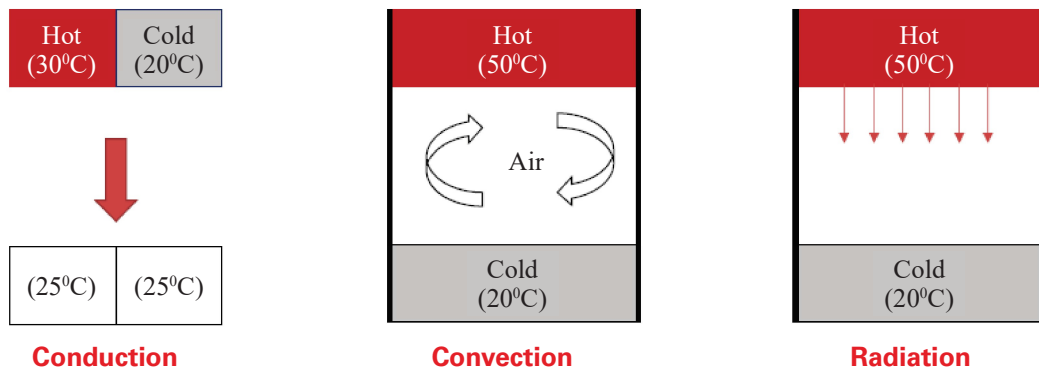
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Building Envelope Design

Figure 30: (a) Components of Building envelope; (b) Three methods of heat exchange



(a) Components of Building envelope



(b) Three methods of heat exchange in buildings

Building envelope is comprised of external walls, roof, floor, ceilings and openings. It acts as barrier between the internal and external environment. The envelope is considered as the boundary to understand its thermal interactions with the external environment through convection, conduction and radiation.

6.1 Modes of heat transfer through the building envelope

Heat transfer through conduction happens through building envelope materials while convective heat transfer occurs due to the motion of air in buildings. Radiation exchange occurs between surfaces with different temperatures. Similarly, short-wave radiation from the sun enters buildings through glass

used in buildings. Long-wave radiation heat gain or loss inside a building happens depending on the inside surface temperatures of the building surfaces and it depends on the insulation of the surface. As seen in the Figure 31, there are specific conditions when each of these modes of heat transfer apply.

6.2 Factors influencing heat transfer in building through envelope

6.2.1 Thermal conductivity

Thermal conductivity is a property that describes the ability of a material to conduct heat. It is a measure of how easily heat can pass through a substance. More specifically, it quantifies the rate at which heat is transferred through a unit area (1m²) and unit thickness (1 m) of material when there is

a temperature difference of one degree (1 K or 1° C) across it. Further, it is typically denoted by the symbol “k” and is expressed in units of watts per meter-kelvin (W/m.K). It is denoted by the equation below.

$$K = \frac{Qd}{A\Delta T}$$

Where,

k = thermal conductivity (W/(m.K))

Q = amount of heat transferred (W)

d = distance between the two isothermal planes (m)

A = area of the surface (m²)

ΔT = difference in temperature (K)

6.2.2 Thermal transmittance (U-Value)

Thermal transmittance is the rate of transfer of heat through a building structure. The thermal transmittance of any building structure (such as wall, roof, floor etc) is expressed as a U-value. The U-value is the reciprocal of air-to-air resistance. The values of surface conductance and surface resistance are given in Appendix -5B. U- Values for everyday constructions are given in Appendix 5C, The U-value of any particular composition can be computed with the following formula.

$$U = 1/R_{a-a}$$

Where, R_{a-a} = air to air resistance

$$R_{a-a} = \frac{1}{f_0} + R_b + \frac{1}{f_i}$$

$$R_b = R_1 + R_2 + \dots \dots \dots R_n$$

Where,

f_0 = outside surface conductance (m²K/W)

f_i = inside surface conductance (m²K/W)

R_b = summation of resistances of all the materials used (m²K/W)

An example of the calculation of the U-value is given in Appendix - 9

6.2.3 Thermal Resistance (R-value)

Thermal resistance is the ability of a material to prevent the passage of heat. It is the thickness of the material divided by its conductivity. This is expressed as m²K/W. The R-value is the reciprocal of the U-value.

6.2.4 Thermal mass

It is the property of the mass of a building that enables it to store heat, providing “inertia” against temperature fluctuations. Building materials can retain some of the thermal energy passing through them depending on their mass, thickness and specific heat capacity. High thermal mass is beneficial in places conditioned with high diurnal variation of temperature. During daytime, walling materials with high thermal mass store heat as it tries to flow indoors. However, during nighttime, the stored heat is then released slowly, helping to keep the indoor temperature more stable and comfortable. Heat stored in a thermal mass can be calculated from the following equation:

$$Q = m \times c \times \Delta T$$

Where,

Q = Heat Stored (J)

m = Mass (kg)

c = specific heat capacity (J.kg/K)

ΔT = temperature difference (K)

Figure 31: Heat transfer in building envelope

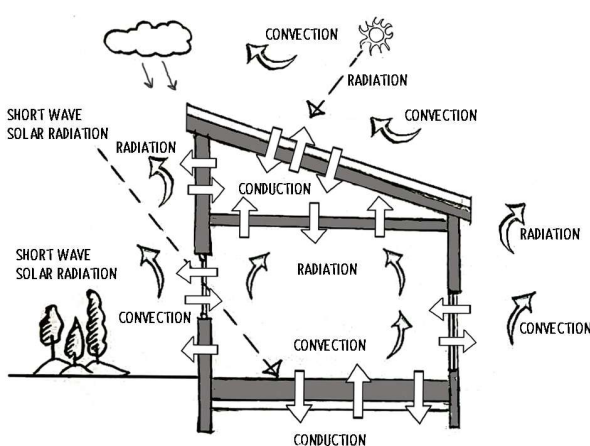


Figure 32: Cavity wall

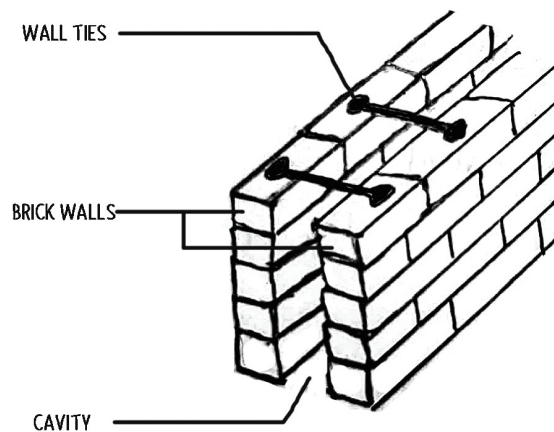


Table 4: Relevant matrix for building envelope elements in terms of heat transfer (Rawal, R., 2021)

Parameter	Metric	Building envelope element
Thermal Conductivity	R value - U value	Walls
Thermal Mass	Specific heat capacity	<ul style="list-style-type: none"> • Internal • External
Thermal Conductivity (Frames and Glass)	R value - U value	Fenestration
Solar Gains	Solar Heat Gain Coefficient	<ul style="list-style-type: none"> • Windows • Skylights • Doors
Visible Light Transmittance	VLT	
Thermal Conductivity	R value - U value	Roofs
Thermal Emissivity	Solar Reflectance	Floors Foundations

6.2.5 Solar reflective index (SRI)

Solar Reflective Index (SRI) value is a combined metric used to indicate the reflectance and emissivity values of solar irradiation of roofing materials. High SRI value correlates to a desirable combination of high reflectance and emissivity in the context of cooling-dominated climates. Higher solar reflectance (R_{sol}) reduces solar heat gain and higher emissivity (E) enhances thermal radiative cooling.

6.2.6 Solar heat gain coefficient (SHGC)

SHGC is the fraction of solar radiation admitted through a glass-either transmitted directly and/or absorbed- and subsequently released as heat inside a home. SHGC ranges from 0 to 1, with a lower value indicating less solar heat gain and a higher SHGC means that a window or glazing system allows more solar radiation to pass through, resulting in more heat gain inside the building.

6.2.7 Visible light transmission (VLT)

One of the key purposes of the window is to provide daylight inside the space. The glass property to indicate the amount of visible light entering through the glass inside the space is known as Visible Light Transmission (VLT). VLT is expressed in a number from 0 to 1. Higher the VLT, the greater the amount of light passing through the glass, and vice versa.

6.3 Components of building envelope

6.3.1 Walls

Due to large surface areas, walls are the biggest source of conductive heat transfer. The heat flux

through wall depends upon thickness, temperature difference and thermal conductivity of the material. The R-value or U-value of all external walls determine how the heat transfer through the wall in the buildings.

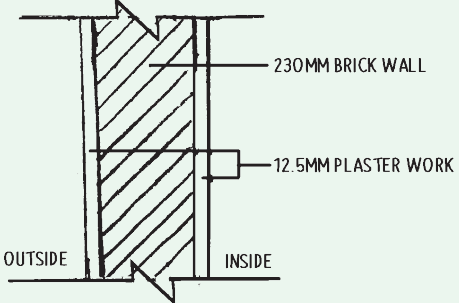
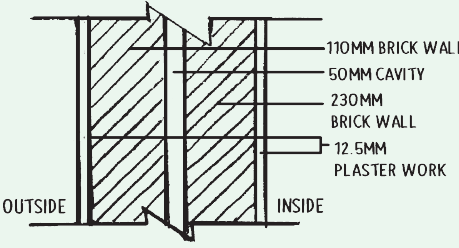
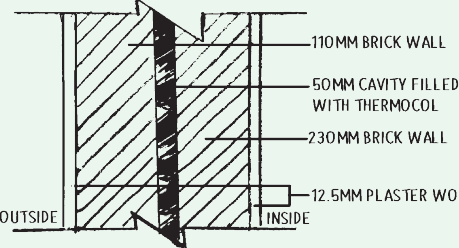
6.3.1.1 Thermal insulation of wall

Insulation in walls can be categorized into three types: external, intermediate, and internal, based on where the insulation is located in the wall assembly. Common insulation materials include polystyrene foam, rock wool, glass wool, aerated concrete, and expanded perlite. Natural options like cellulose and straw can also be used. With their high thermal resistance value, they act as effective barriers to heat exchange between the exterior and interior. Placing the insulation on the outside of a wall (external insulation) is generally considered better than installing it on the inside (internal insulation) as it offers superior energy efficiency, minimizes disruption to interior space, and reduces the risk of condensation issues, although external insulation might be more expensive to install initially.

6.3.1.2 Air cavities

Air cavity walls are also used as insulation. Cavity walls consist of two separate walls, called skins or leaves, with a cavity or gap in-between. Skins are commonly masonry such as brick or concrete block constructed for giving better thermal insulation to building. They also prevent dampness from entering and act as sound insulation. Size of cavity varies from 4-10 cm. Inner and outer wall should not be less than 10 cm each (half brick). If an air space or cavity

Table 5: Comparison of U Value of Brickwork Wall Assembly

Brickwork Wall Assembly	U-value (W/m ² . K)
	<p>230 mm brick wall with 12.5 mm plasterwork in both side</p> <p>2.19</p>
	<p>50 mm cavity with 110mm outer wall and 230 mm inner brick wall with 12.5mm plasterwork in both sides.</p> <p>1.36</p>
	<p>50 mm cavity filled with thermocol with 110 mm outer wall and 230mm inner brick wall with 12.5 mm plasterwork in both sides.</p> <p>0.52</p>

is enclosed within a body, through which the heat transfer is considered, this will offer another barrier to the passage of heat. It is measured as the cavity resistance, (R_c). An unventilated cavity is a good insulator ($R = 0.15 \text{ m}^2\text{degC/W}$), equal to about 180 mm brick wall (Koenigsberger, et al., 1973). Cavities can be filled with other insulation materials to obtain greater insulation value.

6.3.2 Roof

The heat transferred through roofs can be considered similar to walling material in terms of thermal conductivity and the relevance of U-value. However, to reduce heat gains in a sub-tropical climate, the roof surface exposed to the outdoors can be treated with coatings that increase solar reflectance. The roof is, without a doubt, the most important component of the entire building surface. Out of all the components of a building envelope, the roof experiences maximum quantity of solar radiation incident on a building. There are various

passive measures to regulate heat gain through the roof such as shading the roof, insulating the roof, roof garden, roof pond, reflective roof etc.

6.3.2.1 Shading the roof

In a sub-tropical climate, the most effective method for shading the roof is to construct a second roof over the first with an attic space (double roof), as in the traditional buildings. Since the outer roof gains heat through radiation and reaches a very high temperature, it is imperative to separate it well from the main roof, allow heat dissipation from the space between the two roofs, and use a reflective surface on both. The surface of the lower roof should be reflective for the low temperature (long infra-red) radiation, emitted by the upper roof.

6.3.2.2 Insulating the roof

Roofs can be insulated either over the deck or under the deck. Generally over deck insulation is preferred.

6.3.2.3 Roof pond

The basic concept of a roof pond is to use water as an ideal thermal mass as it is cheap, non-toxic and has a large volumetric heat capacity for passive heating and cooling. From different passive cooling techniques, evaporation has been identified as the most efficient way to reduce internal temperature in sub-tropical climates. The same procedure is used in roof ponds where the water absorbs the heat contributing to the reduction of internal temperature and cooling the internal spaces. However, proper care should also be given to waterproofing and structural safety.

6.3.2.4 Reflective roof

Due to the absorptance property of roofing finishes, their surface temperatures tend to be significantly higher than surrounding air temperatures in hot climates. Some of the heat absorbed by the roof surface may be lost to the outdoor air through convective heat transfer from winds. However, prioritizing the removal of remaining heat will prevent its transfer to indoors through conduction. This can be achieved by using roofing and/or roof coating materials with high emissivity values. Roof coating materials such as paints, tiles, sheets with high reflectance and emittance values are available. They are usually termed as products with high Solar Reflective Index (SRI) values. Solar Reflectance Index (SRI) indicates the roof's ability to reject solar heat, and is the combined value of reflectivity and emittance. High SRI value correlates to desirable combination of high reflectance and emissivity in the context of cooling-dominated climates. Based on several studies, roughly 88% of UV rays are reflected off a white silicone roof compared that with a 17% average for non-reflective roofs. Some

of the most popular materials used for cool roofing are terracotta or clay tiles, reflective metal roofing like aluminum, steel and copper, painting light colors in roof, concrete tiles, membrane roofing (made from flexible, sturdy, waterproof combination of polyester, felt or fiberglass and connected with asphalt, polymer or synthetic rubber), solar panels etc. This principle can be implemented in sub-tropical climate.

6.3.2.5 Green roof

The use of vegetation on roofs of buildings is a common practice in the architecture of older buildings in countries like Iceland, Scandinavia, Switzerland, Germany and Tanzania hitherto known as green roofs to protect from the wind and provide insulation for winter warmth, shade and cooling during hot summers evapotranspiration, and to enhance the aesthetic value of the building. Modern advancement has opened for the use of a wide range of vegetative systems in the green roof. Green roof systems can be broadly categorized into two types: intensive and extensive, based on the depth of the soil substrate. Intensive green roofs typically have a soil substrate depth exceeding 150 mm, while extensive green roofs have a soil depth ranging from 25 mm to 150 mm. When evaluating green roofs, it is essential to consider both their advantages, such as radiative cooling, and their disadvantages, including high costs, weight, and maintenance requirements.

6.3.3 Fenestration

It typically involves optimization of window wall ratio, enhancing window airtightness, and window thermal performance with inert-gas-filled multiple layered glazing, Low-emissivity (low-E) technologies,

Figure 33a: Double roof

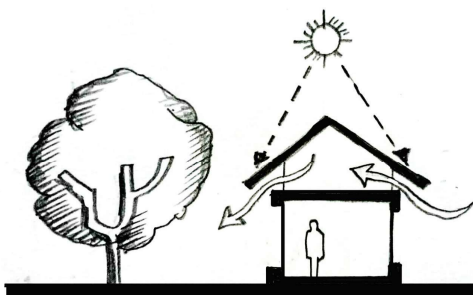


Figure 33b: Green roof

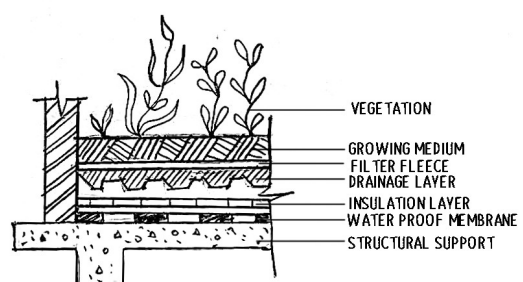


Figure 33c: Interaction of roofing materials and surfaces with incident solar radiation.

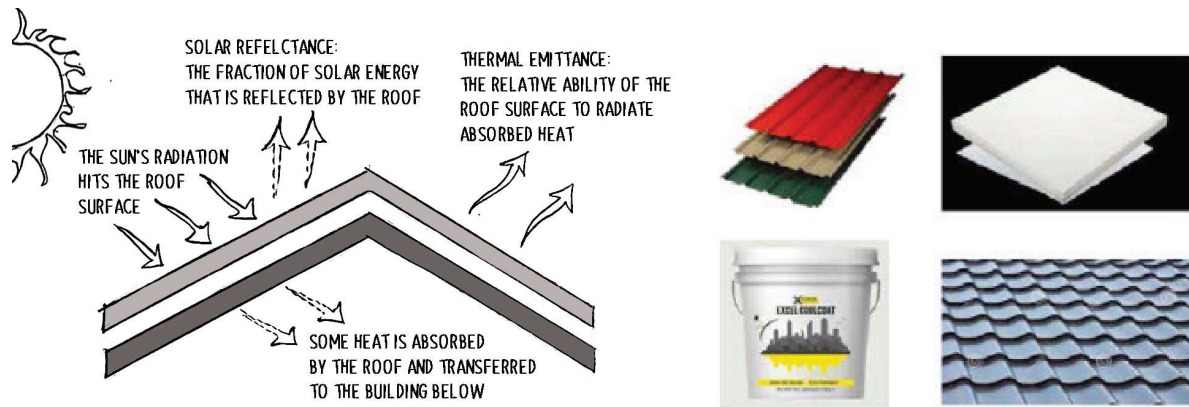
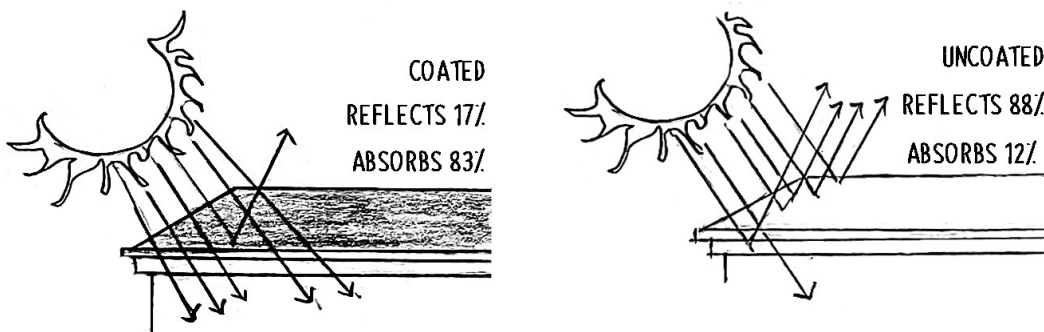


Figure 33d: Properties of reflective roof



etc. The orientation of windows and glass sections should account for various amounts of light entering the building from the east, west, north, and south to meet the heating and cooling requirements of the building. For this, windows can be installed with:

- Double or multiple-layered glass pan
- Low emissivity
- Inert gas fill (Argon etc.)
- Insulative spacers
- Insulated frames, thermal breaks

For fenestration systems, conductive heat gains are determined by the U-values of the window assemblies including skylights. Moreover, solar heat gains through fenestration are affected by the type of glazing. SHGC of the glazing will determine the amount of heat transfer through the transparent glass surfaces whereas VLT determines the amount of daylight entering the space. Hence, glass with a higher VLT value is desirable for naturally-lit spaces.

High-performance glazing can contribute to optimizing energy usage and at the same time enhance light penetration. It has low U-value, low shading co-efficient and high VLT (Visual Light Transmittance) and is the ideal choice for today's energy-stressed buildings. The shading coefficient indicates the extent of direct solar heat gain. Generally, for SHGC, we multiply the solar coefficient by 0.87. Typical values of high-performance glass are shown in the table below.

Table 6: Typical values of high-performance glass (CAMTECH, 2009)

Property	Range
Shading coefficient	0.1 - 0.4
U-value	1.7-3.0 W/m ² . K
Visual light transmittance	40%-60%

6.3.3.1 Window to wall ratio:

Another passive design strategy to control the heat ingress in buildings through glazing is optimizing

Figure 34: Movable shading device

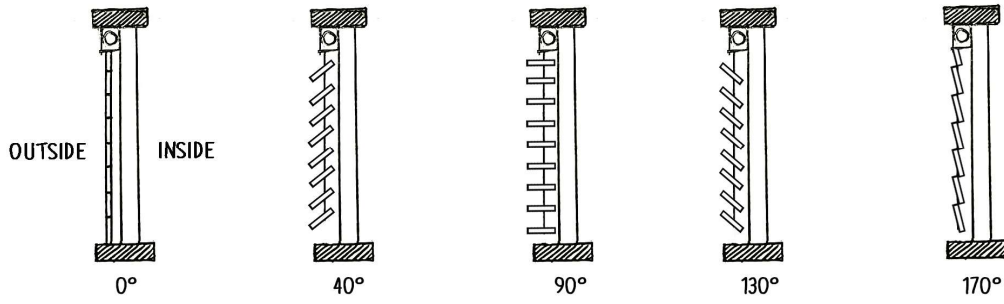


Figure 35a: Shading by overhangs

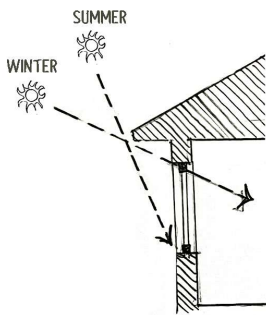


Figure 35b: Overhang design for shading

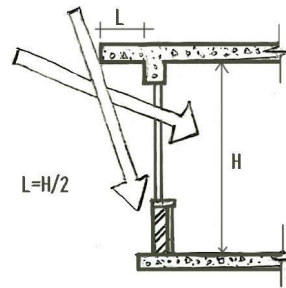


Figure 35c: Horizontal sun shading device

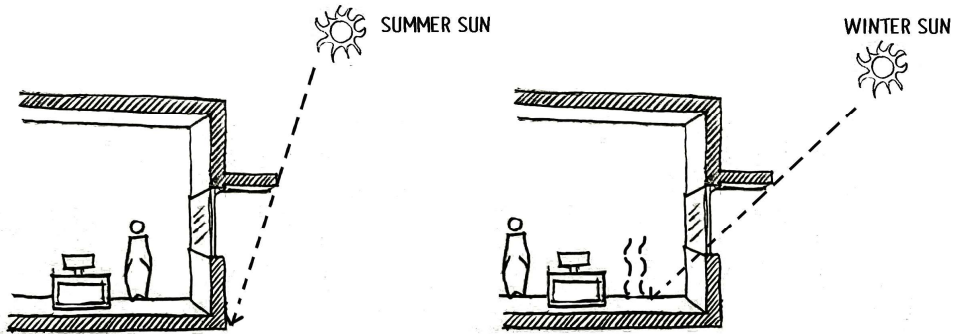


Figure 35d: Vertical shading devices

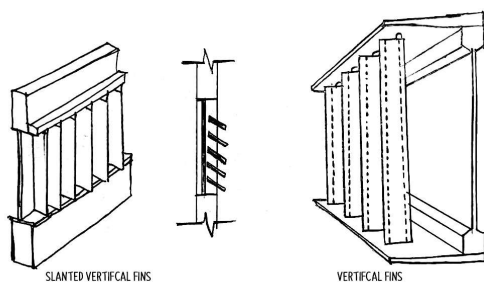


Figure 35e: Egg-crate devices

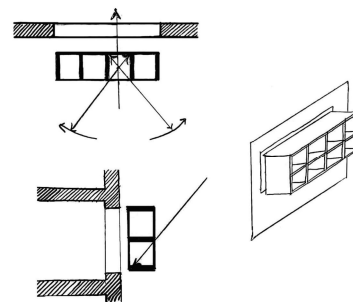


Figure 36a: Different shading devices

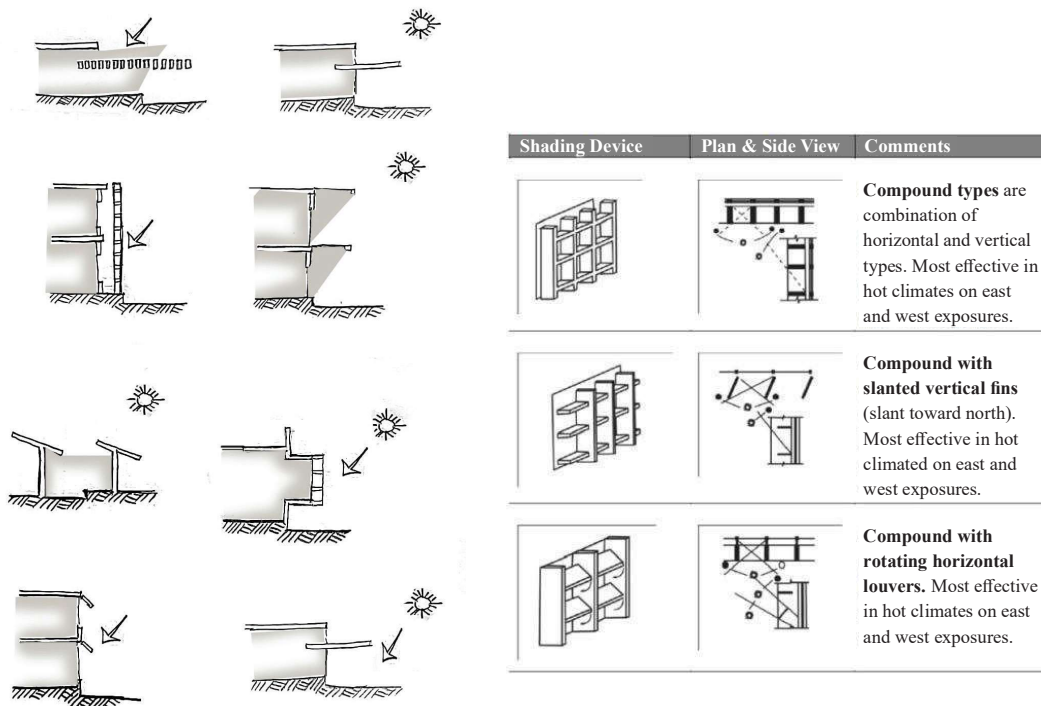


Figure 36b: Use of vegetation to naturally cool buildings during summer and provide shelters from prevailing winter winds

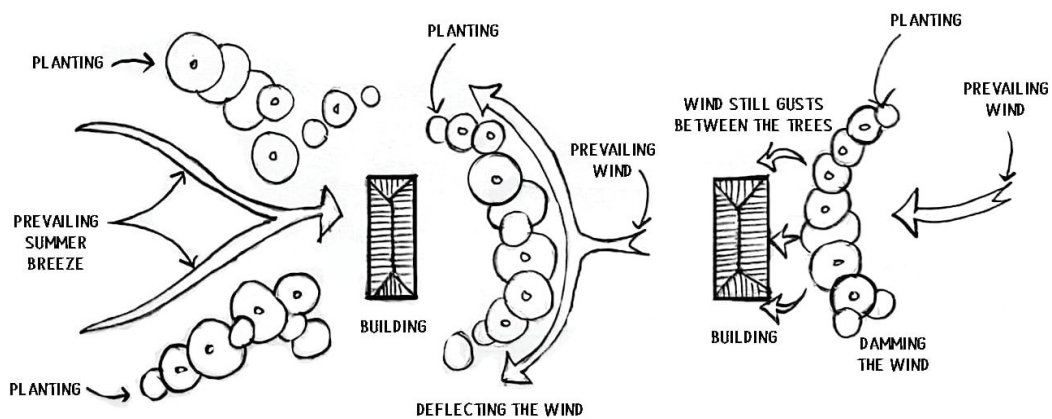


Figure 36c: Deciduous trees allow sun penetration in winter and blocks sun access during summer

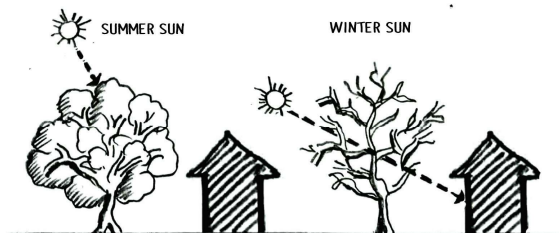
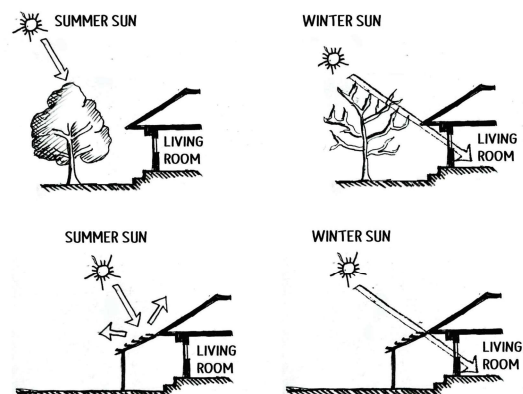


Figure 36d: Shading by vegetation



the ratio of glazed area to total wall area referred to as window-to-wall area ratio (WWR). Determining the WWR helps to bring accuracy to predictions of the contribution of radiative heat transfer through windows towards the total cooling or heating load of the building.

6.3.3.2 Shading devices

The devices that are used to block the solar radiation incident on the exposed surfaces of a building, consequently reducing heat gain, are called shading devices. Shadings are normally done in the openings. Shading strategies for the glazed components of building façade also offer reduced cooling loads for the buildings which can be achieved by layout (getting shadow from surrounding buildings, etc.), architectural form (getting shadow from arcade, balcony, etc.), building shading components (outside building or inside building), and plants (Yi & Bing, 2017). Movable shading, shutter and reflection can help in the reduction of solar penetration of windows and other glass areas. Large roof projection not only prevents from monsoon rain but also helps in avoiding summer sun. Similarly, perfectly designed shading device also prevents summer sun. The different types of shading devices are discussed below.

a) Internal sun shading devices

- The internal devices may be Venetian blinds, roller blinds and curtains.
- Internal shading devices only limits the glare resulting from solar radiation but not the heat coming into the room through the windows.
- Usually are adjustable and allow occupants to regulate the amount of direct light entering their space.

b) External sun shading devices

- The external shading devices are much more effective than the internal arrangement as they control the amount of radiation entering the building externally.
- It is true that more than 90% of heating effect of solar radiation through window glass is possible to eliminate with efficient use of the shading devices.
- Overhangs and projections should be such that it allows winter sun to penetrate into the building and reduce overheating during summer.

- They can be any mechanical equipment (like movable device), projections (chajjā), cantilevers, louvres, fins, jālis, or even textiles.
- They can be fixed, manual and automatic moveable.

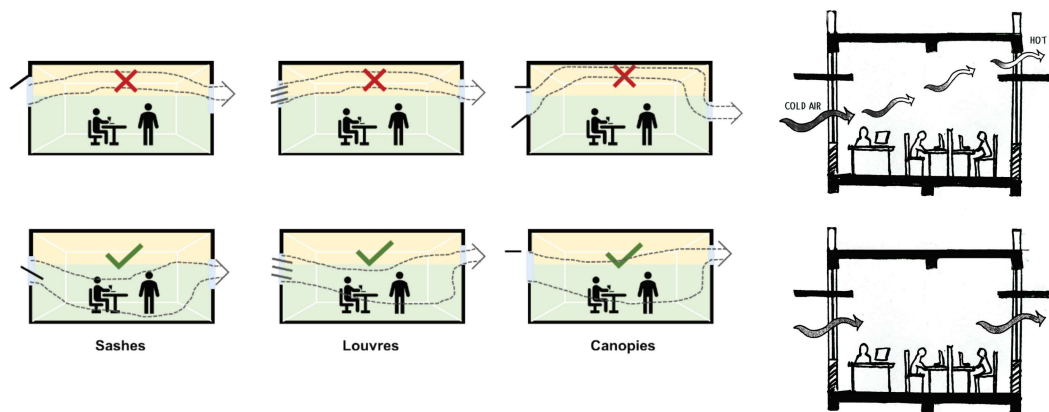
The thumb rule for providing horizontal shading device in latitude less than 28°N is projection (L) is half the window height (H) (NGBG, 2015).

They should be provided above window openings.

- Fixed or movable shading devices can be chosen depending on the trajectory of sun and direction of the façade. Shutters, jālis, and vertical screens can also act as effective shading strategies to reduce radiative heat transfer (BEE, 2021).
- Horizontal devices are to shade a window during hot summer months, but to allow sunlight to shine through a window in the winter, to help warm a building.
- Vertical devices are primarily useful for east and west exposures because of the low incident angle of sun. However, this type of shading devices is useful in south direction as well in sub-tropical climate to cut off the direct solar radiation from the window.
- Egg-crate devices are the combination of vertical and horizontal shading elements commonly used in hot climate regions because of their high shading efficiencies. The horizontal elements control ground glare from reflected solar rays. The device works well on walls.

c) Shading by vegetation

- Plantation of deciduous trees facilitates blocking summer sun and permit winter sun into the building.
- Provision of soft ground surface in the surrounding that helps to absorb solar radiation and reduce heat island effect.
- Trees should be planted within a distance of 1.5m -6m from the building depending on their height and species (Vasiu, 2013).
- Creation of green corridor to direct prevailing summer wind into the building.
- Similarly, during winter, the trees should act as shelter from intrusive winds.

Figure 37: Position of overhangs and louvers to improve the ventilation

- Planting trees either in concave or convex shape relative to that of the building provide viable solutions for both deflecting and damming the wind.
- Plantation of deciduous trees to allow winter sun and avoid summer sun and also to allow cool breeze into the building.
- Provision of soft ground surface in the surrounding that helps to absorb solar radiation and reduce heat island effect.
- Implementing green roof design or plantation on roof to reduce heat island effect.

6.3.3.3 Windows design for natural ventilation

Natural ventilation is defined as the provision of fresh air and removal of stale air using the naturally occurring forces of wind and buoyancy to drive airflow through intentional openings in the building envelope. In hot climates, it can also improve thermal comfort by removing heat from inside the building. Approximately, Ventilation improves thermal comfort by:

- Cooling of indoor air by replacing or diluting it with outdoor air as long as outdoor temperatures are lower than the indoor temperatures.
- Cooling of the building structure i.e., Thermal mass of the building.
- Providing a direct cooling effect over the human body through convection and evaporation.

Natural ventilation can be induced by wind pressure or in the form of a stack effect resulting from temperature-induced pressure differences between

indoor and outdoor air. When outside and indoor temperatures are closer, these forces are small, presenting a challenge for NV design. Typically, NV systems are designed to ensure that buoyancy forces alone can provide adequate NV flow rates in the absence of winds. Since moving air or wind is obstructed by the building, on the windward side, higher pressure is created. Further, as the air moves over and around the building towards the leeward side, the pressure gradually reduces and air speed increases. The pressure differences generated between indoors and outdoors drive ventilation flow. Additionally, exterior pressure increases with height, providing design flexibility and allowing variations in fenestration details on various floors of the residential building.

Inside a space, warm air rises and forms a layer of buoyant air near the ceiling. The buoyant air creates a hydrostatic pressure in the area. Compared to this pressure, the outside pressure at the same height is lower. Hence, the buoyant force moves hot air outdoors from the inside space at heights near the ceiling. Closer to the floor, openings at the lower level allow cooler outside air to enter the space where the pressure balance is inverse to that near the ceiling.

Wind-driven:

- Relies on wind pressure to drive air movement.
- When wind hits the windward facade, it creates a positive pressure on the facade. Similarly, as it flows away from the leeward facade, a region of lower pressure will be created. This pressure difference will force air movement.

Buoyancy driven:

- Describes the natural movement of air through a building resulting from differences in vertical pressure developed by temperature differences in the air.
- This occurs in a building by warm air escaping from openings at a substantial height on the building envelope, which draws in colder, denser outside air through the lower openings of the building.

General guidelines for natural ventilation

- Orienting the window in a favorable wind direction.
- Casement windows provide more operable area than a sliding window of the same size (90% openable areas in casement window and 50% openable area in sliding window).
- Position of overhangs, louvres etc. can be used to direct the air inside at the required level and area Improving side ventilation with mosquito net. The reduction in air volume flow due to the application of mosquito nets should be taken into account.

6.3.4 Surface finishes

Surface treatment and the selection of surface materials will also influence the thermal behavior of the building and can help in reducing the heat load. Light-colored or shiny external surfaces will reflect a large part of the incident solar radiation; thus, much less heat will enter the building fabric. On the other hand, darker colors absorb more heat, which can be beneficial in colder climates. The texture of a material can also impacts its solar radiation absorption. Rough texture material is found to absorb more solar radiation for longer periods and results in heat gain while smooth surface reflects solar radiation and hence reduces heat by building. So, when considering the texture of a material, it's important to evaluate its potential impact on solar radiation absorption.

6.4 General Guidelines for building envelope design in different climatic zones of Nepal

6.4.1 Sub-tropical climate

In the sub-tropical region, our main target is to:

- reduce solar radiation falling on the building envelope.

- reduce external heat gains through the building envelope.
- remove excess heat that has built up inside through ventilation

For this, different components of the building need to be designed accordingly.

Walls:

- The surface area of the wall should be minimized in the east and west directions.
- Wall assembly should have a low U-value. Which can be achieved by providing air cavity, insulation or thermal mass.
- Wall should be shaded as much as possible from the direct sunlight by vegetation (See details in section 6.3.1).
- The insulation should be provided in the east and west walls to mitigate the effects of substantial solar radiation which causes these walls to heat up considerably.

Roofs:

- Roof assembly should have a low U-value to reduce conduction heat gains and loss through the roof. This can be achieved by providing insulation and high SRI value of roofing materials.
- Green roof recommended.

Fenestration:

- Fewer windows in the east and west directions.
- Window to wall ratio as recommended by the Mahoney table i.e. 25-40% at body height.
- Glass with lower U-value (can be achieved by providing double glazed) to reduce conduction heat gains and loss through the glass. Low SHGC and high VLT are recommended.
- Windows should be shaded properly from unwanted direct solar radiation by providing horizontal, vertical and egg-crate shading devices (Refer to the details in section 6.3.1). (See Appendix 2 for the calculation method).
- Should have natural ventilation provision either wind-driven or buoyancy-driven.

Surface finishes:

- Light color and smooth textures of the wall is recommended.

6.4.2 Warm Temperate Climate

In the sub-tropical region, our main target is to:

- reduce solar radiation falling on the building envelope in summer.
- reduce external heat gains through the building envelope in summer.
- remove excess heat that has built up inside through ventilation in summer.
- optimize solar access inside the building during winter.

For this, different components of the building need to be designed accordingly.

Walls:

- The surface area of the wall should be minimized in the east and west direction.
- Wall assembly should have a low U-value. Which can be achieved by providing air cavity, insulation or thermal mass.
- Wall should be shaded as much as possible from the direct sunlight by vegetation (see details in section 6.3.1).
- The insulation of the east and west walls is crucial due to significant solar radiation, which causes these walls to heat up considerably.

Roofs:

- Roof assembly should have a low U-value to reduce conduction heat gains and loss through the roof. This can be achieved by providing insulation and high SRI value of roofing materials.
- Green roof recommended.

Fenestration:

- Fewer windows in the west direction.
- Window to wall ratio as recommended by the Mahoney table i.e. 25-40% at body height.
- Glass with lower U-value (can be achieved by providing double glazed) to reduce conduction heat gains and loss through the glass. Low SHGC and high VLT are recommended.
- Windows should be shaded properly from the direct sunlight in summer (see details in section 6.3.1).
- Windows should have natural ventilation provision either through wind-driven or buoyancy-driven.

Surface finishes:

- Light color and smooth textures of the wall is recommended

6.4.3 Cool temperate climate

In warm and cool temperate regions our main target is to:

- reduce solar radiation falling on the building envelope during summer.
- reduce external heat gains through the building envelope during summer.
- remove excess heat that has built-up inside through ventilation during summer.
- optimize solar access inside the building during winter.
- reduce heat loss from inside to outside through the building envelope in winter.

For this, different components of the building need to be designed accordingly.

Walls:

- The surface area of the wall should be minimized in the east and west direction.
- Wall assembly should have a low U-value. Which can be achieved by providing air cavity, insulation or thermal mass.

Roofs:

- Roof assembly should have a low U-value to reduce conduction heat gains and loss through the roof. Which can be achieved by providing insulation.
- Green roof is recommended.

Fenestration:

- Fewer windows in the west direction.
- Window-to-wall ratio as recommended by the Mahoney table i.e. 25-40% in north and south walls at body height.
- Glass with lower U-value (It can be achieved by providing double glazed) to reduce conduction heat gains and loss through the glass. High SHGC and high VLT is recommended.
- Windows should be shaded properly from the direct sunlight by providing horizontal shading devices (to let in winter sun inside the room) (see details in section 6.3.1). Which can be calculated as in appendix - 2.

- Natural ventilation as much as possible either through wind driven or buoyancy driven.

Surface finishes:

- Light color and smooth textures of wall is recommended

6.4.4 Alpine climate

In Alpine climate our main target is to:

- optimize solar access inside the building during the day.
- reduce heat loss from inside to outside through the building envelope
- prevent cold draughts in the building.

For this, different components of building need to be designed accordingly.

Walls:

- Surface area of wall should be maximized in south direction.

- Wall assembly should have low U-value which can be achieved by providing air cavity, insulation or thermal mass.

Roofs:

- Roof assembly should have low U-value to reduce conduction heat gains and loss through the roof which can be achieved by providing insulation.

Fenestration:

- Less window or no window at north and windward direction.
- Window to wall ratio as recommended by the Mahoney table i.e. 25-40% in south direction.
- Glass with lower U-value (can be achieved by providing double glazed) to reduce loss through the glass. High SHGC and high VLT is recommended.

Surface finishes:

- Dark color and rough textures of wall is recommended.

Chapter 7

Sustainable Building Material

- >> Sustainable building materials
 - >> Need of Green and Sustainable Construction Materials
 - >> APPROACH to Consider When Selecting Sustainable Building Materials
-



Bayalpata Hospital, Accham by Sharon Davis Design in 2019 in Rammed earth
Source: <https://architizer.com/idea/3082345/>



*Bayalpata Hospital, Accham by Sharon Davis Design in 2019 in Rammed earth
(Source: <https://architizer.com/idea/3082345/>)*



*Mato Ghar, Budhanilkantha, Kathmandu
Material: Rammed Earth, Adobe, cob, bamboo; Concept: Prabal Thapa, Hemendra Bohora
Engineering contractors: ABARI (Bamboo works), Adarsha Nirman, Ghampani Urja
(Source: <https://prabalthapaarchitects.com.np/mato-ghar>)*

7

Sustainable Building Material

Building materials play a crucial role in sustainable building design, influencing extraction, processing, and transportation throughout the building's lifecycle. They impact greenhouse gas emission, heat flow, energy storage, and overall thermal performance of the building. In Nepal, traditional materials are still popular due to their availability, low cost, and compatibility with the local climate as well as being managed by skilled local labor. However, there is a growing shift towards modern, imported materials which tend to have a higher environmental footprint.

The chapter highlights the importance of balancing traditional materials and practices with innovative approaches, recommending the integration of alternative sustainable materials and optimized building designs that can reduce costs and resource use while improving comfort, health, and environmental performance.

7.1. Sustainable building materials

Sustainable building materials (SBM), often called green or eco-friendly materials, are designed to offer environmental, social, and economic benefits throughout their lifecycle— from the extraction of raw materials to manufacturing, usage, and final disposal. Despite extensive research on material selection, a universally accepted definition for “sustainable building materials” has yet to be established (Franzoni, 2011; Saghafi & Teshnizi, 2011). This lack of consensus can complicate the development of guidelines and principles needed to standardize sustainable materials in construction.

Sustainable building materials are characterized by their ability to conserve resources, reduce waste, and minimize their ecological footprint. These materials aim to meet construction needs without compromising environmental quality or human health. Key attributes of SBM include:

1. Low Embodied Energy
2. Local Availability
3. Predominantly Renewable Source
4. Construction techniques compatible with local knowledge and skills
5. Reusability and Recyclability
6. Efficient use of resources during manufacturing and construction
7. Durable and Low Maintenance
8. Affordable/Cost-Effectiveness
9. Safe and reliable structural integrity and suitable for various construction needs.
10. Easy to use and socially acceptable
11. Non-toxic (avoid releasing pollutants), contributing to a comfortable and healthy indoor environment,
12. Minimal Pollution in the entire lifecycle

Figure 38: Key attributes of SBM

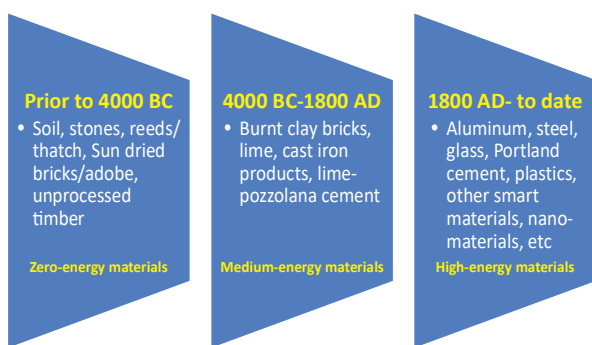


By incorporating these materials, the construction industry can reduce its impact, conserve resources, and improve overall resilience while supporting healthier, more sustainable built environments

7.2. Need of Green and Sustainable Construction Materials

Construction materials have evolved continuously from traditional, locally sourced zero energy options like stone, wood, and mud to modern materials such as cement, steel, aluminum, glass, plastics and other smart and nano materials (See Figure 39). While this shift has delivered benefits in terms of durability, low maintenance, and convenience, it has also introduced environmental challenges.

Figure 39: Evolution of Building Materials in history



Modern materials often require energy-intensive production and negatively impacting natural resources. They can emit harmful volatile organic compounds (VOCs) that jeopardize occupant health and possess poor thermal properties, leading to discomfort and reliance on artificial climate control systems. This dependency raises energy demands and costs, counteracting energy efficiency efforts. Thus, these imported modern materials increase both initial and operational costs with their high environmental footprint and toxicity, further heightening resource consumption and undermining sustainable building initiatives

Given the urgent need to address climate change, resource depletion, and promote resilient, environmentally responsible infrastructure and sustainable urban development, it is crucial to re-evaluate the materials used in construction. Prioritizing sustainable and locally sourced materials, we can create ecologically responsible

buildings that align with environmental goals and enhance human health. Prioritizing sustainable and locally sourced materials contribute to more ecologically responsible buildings that align with environmental goals and enhance occupant health and well-beings.

The key reasons emphasizing the needs of SBM are:

- **Improve Human Health and Well-being:** Green construction materials enhance indoor air quality and thermal comfort, reducing harmful emissions and improving occupants' health and quality of life.
- **Environmental Impact Reduction:** Sustainable materials lower carbon footprints and minimize waste, helping to mitigate the environmental effects of construction activities.
- **Resource Conservation:** Sourced from renewable resources, green materials decrease reliance on finite materials and promote energy and water efficiency, leading to a more sustainable future.
- **Enhancing Resilience to Multi-Hazards:** These materials improve resilience to climate change and local environmental conditions, aiding in disaster preparedness and recovery.
- **Socio-Economic Benefits:** The use of sustainable materials generates economic advantages, including long-term cost savings and local job creation, supporting a transition to a sustainable construction sector.
- **Supporting Decarbonization and SDGs:** Green materials support national and international commitments, contributing to the United Nations Sustainable Development Goals (SDGs) by reducing carbon emissions and promoting sustainable practices essential for a resilient future

7.3 APPROACH to Consider When Selecting Sustainable Building Materials

In selecting sustainable building materials, it is essential to integrate optimization strategies and assess environmental impacts across the lifecycle of each material. The following approaches highlight the key considerations for choosing materials that promote sustainability and minimize the environmental impact of construction.

7.3.1 Optimization and alternative materials

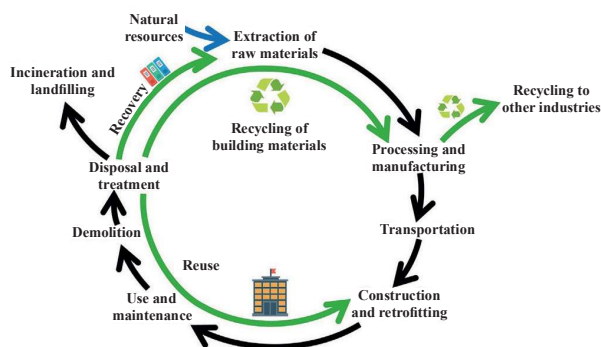
Green building practices require a focus on optimizing material use and incorporating sustainable alternatives to minimize environmental impacts throughout a building's lifecycle. This involves efficient sourcing, use, and management of materials from construction through to deconstruction. Key Strategies for Material Optimization and Alternatives:

- Optimize resource use to minimize waste, energy consumption, and carbon footprints.
- Employ design strategies like efficient structural systems, prefabricated components, and lightweight materials to reduce material consumption and embodied energy (the total energy used in material production, transportation, and assembly).
- Recognize that materials with high embodied energy, such as cement and steel, are crucial for structural strength and seismic safety; therefore, optimize their use to achieve maximum strength with minimal consumption.
- Consider adopting load-bearing systems over reinforced concrete frames to reduce cement and steel usage, and optimization of materials thereby minimizing environmental impacts.

7.3.2 Life Cycle Analysis (LCA)

Life Cycle Assessment (LCA) of building materials intends to assess the degree of sustainability of building material and its technology and the process of choosing SBM based on the three pillars of sustainability; environment, social and economic.

Figure 40: Life Cycle of Building Materials



As per ISO 14040:2006 and ISO 14044:2006 standards, LCA quantifies the potential environmental impact of a product or a service. This is a technique for assessing environmental impacts associated with every stage of the entire life cycle of a material, from cradle to grave (see Figure 40) i.e., from raw material extraction through processing, manufacture, distribution, use, repair and maintenance, to disposal or recycling of the materials. LCA can provide quantitative and comparative values for the environmental impacts of various building materials and technologies (Singh et al 2011; Zabalza Bribián et al 2011; Takano et al 2015). It provides valuable insights into It provides valuable insights for architects, engineers, policymakers, and other stakeholders to compare and make informed decisions for selecting sustainable building materials options that reduce the environmental footprint of buildings

This comprehensive analysis for selecting the most appropriate sustainable building material from various alternatives can be conducted using multi-criteria decision-making (MCDM) methods. Accordingly, LCA evaluates multiple relevant criteria and factors, including:

1. Embodied Energy

Embodied energy is a major factor in the LCA of building materials. Reducing embodied energy is a key priority in selecting sustainable materials, as it directly influences the overall carbon footprint of a building. In any building construction, the use of materials with low embodied energy should be considered. Energy for manufacturing is almost the same in all over the world. Transportation to the factory and from the factory to the site can vary from place to place. The following table (Table 6 from National Building Code of India, 2017) provides a classification of building materials based on embodied energy.

2. Greenhouse Gas Emissions

LCA quantifies the carbon emissions associated with each stage of a material's lifecycle. Choosing materials with lower CO₂ emissions should be considered in any building construction to reduce the overall environmental impact of a building.

Table 7 : Classification of Materials Based on Energy Intensity [NBC 2017, India, Clause 9.1.4 (a)]

Sl No. (1)	Category of Material (2)	Energy Intensity (Range) GJ/t (3)	Examples (4)
	Very high energy	>50	Aluminum, stainless steel, plastic, copper, zinc
	High energy	5-50	Cement, steel, glass, bitumen, solvents, cardboard, paper and lead
	Medium energy	1-5	Lime, gypsum plasterboard, burnt clay brick, burnt clay brick from improved vertical shaft kiln, aerated block, hollow concrete block, gypsum plaster, concrete block, timber, wood products, particle board, medium density fiber board, cellulose insulation, in-situ concrete.
	Low energy	<1	Sand, aggregate, fly ash and fly ash-based products, cement stabilized soil block, straw bale, bamboo, stone

1. While comparing the embodied energy of building materials, the total quantity by mass of the material times the embodied energy value per unit mass (energy intensity) of the material to be installed for the same surface area of the building may be compared.
2. The values given in the table are comparative values, and in case of substantial difference in the transportation component of the materials in question, the same should also be taken into account while calculating the embodied energy.

Over the lifetime, a building's carbon footprint consists of the embodied carbon from the manufacture and processing of building materials and construction, as well as the operational carbon from the energy use of its operations. Whole-life carbon is described as a sum of operational carbon and embodied carbon, as calculated over the whole life cycle of the building (Figure 40)

The guideline focuses on the embodied carbon from the manufacture and processing of building materials. Appendix 6.B presents the embodied carbon of certain materials. (Anderson, n.d.)

3. Indigenous or locally available

Materials should be selected locally or regionally available which save energy and resources for transportation of materials to the construction site.

4. Naturally plentiful and Resource Depletion

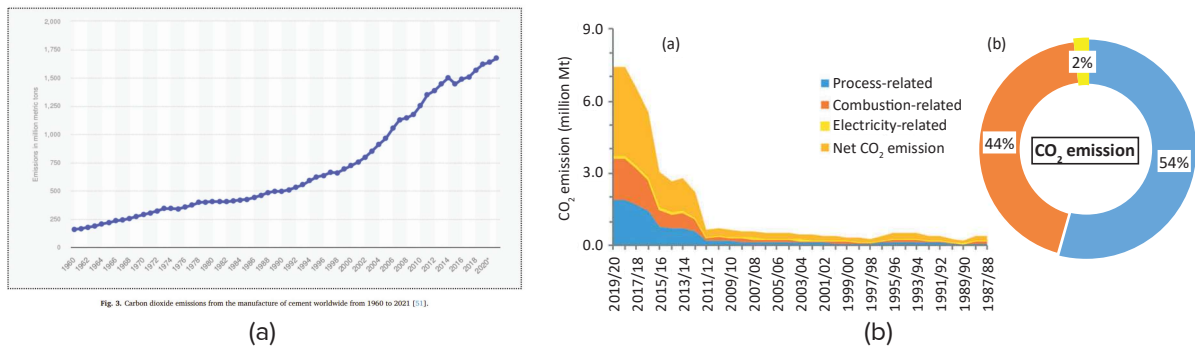
To minimize resource depletion and ensure long-term availability for future needs, efforts should

focus on using materials that are naturally abundant and sustainably harvested, reducing the reliance on finite resources. This approach promotes a balance between development and conservation, supporting more sustainable building practices

5. End-of-Life Impact

LCA also considers how materials can be reused, recycled or safely disposed of at the end of their lifecycle. Materials with high recyclability or potential for reuse can significantly reduce the environmental burden associated with demolition and waste management.

By using LCA to guide material choices, the construction industry can create buildings that are not only resource-efficient but also aligned with global sustainability goals, helping to reduce the sector's contribution to climate change and environmental degradation. The details procedure of quantitative Multi-criteria Life Cycle Assessment (MCLCA) are presented in Annex -9.

Figure 41: CO₂ emissions from the cement industry in Nepal

a) for the 1987-2019 period and b) contribution of different emission activities during the cement production to the net CO₂ emissions in 2019/2020 (Thakuri, S. et al. 2021)

7.4 Recommended Sustainable Materials

For the required quality of the building materials reference should be made National building code of Nepal. General guidelines and recommendations for use of different alternative materials for sustainable construction are presented as follows:

7.4.1 Structural Materials

7.4.1.1 Cement concrete

Concrete is a widely used strong and durable material which provides good thermal mass for buildings. However, cement and concrete production contribute significantly to greenhouse gas emissions, particularly CO₂, necessitating urgent decarbonization efforts (Barbhuiya, S. et al., 2024). Cement production is known for its high energy consumption, which occurs during various processes such as raw material preparation, clinker production and grinding. In addition, extraction and mining of aggregates also results in natural resources depletion and natural habitat destruction results in huge environmental impacts.

Enhancing energy efficiency not only helps to minimize greenhouse gas emissions but also improves the overall competitiveness and economic viability of cement manufacturing. By reducing carbon emissions from these industries, we can make substantial progress in addressing the global climate crisis. Decarbonization aligns with international agreements and targets, such as the Paris Agreement, which aim to limit global temperature rise and combat the adverse effects of climate change

Strategies for decarbonizing cement production involve a range of approaches aimed at reducing carbon emissions and promoting sustainability. They are:

1. use of alternative cementitious materials, such as fly ash, slag and pozzolans, which can partially replace traditional clinker and reduce carbon intensity.
2. carbon capture and storage (CCS) technology - capturing CO₂ emissions from cement plants and storing them underground.
3. improving energy efficiency in cement manufacturing through process optimization, waste heat recovery and energy-efficient technologies is also critical.

The development of low-carbon cements, including blended cements and novel binders, offers greener alternatives. Circular economy approaches, such as recycling concrete waste and utilizing alternative fuels, further contribute to decarbonization efforts in the cement industry.

Several approaches and technologies are being developed to make cement and concrete more sustainable:

A. **Alternative Cementitious Materials:** The following alternative materials can be used to replace or supplement Portland cement, which is the primary binder in conventional concrete:

- **Fly Ash:** A byproduct of coal combustion, fly ash can be used as a supplementary

cementitious material, reducing the need for ordinary Portland cement and lowering carbon emissions. It can be mixed in concrete to help increase its workability. At the same time, it also makes concrete more durable in the long-haul so it reduces instances of cracking, bleeding, and permeability. Fly ash is an excellent option for a more cost-effective material compared to cement,

- **Slag Cement:** Ground granulated blast furnace slag, a byproduct of steel production, can replace a portion of Portland cement in concrete, offering similar performance properties while reducing environmental impact. These alkali-activated binders offer similar or even superior mechanical properties compared to traditional cement and have demonstrated durability in various applications (Barbhuiya, S. et al., 2024)
- **Rice Husk Ash:** Rice husk ash is a waste product of rice milling that is known for its high silica content. It can be used for increasing the strength of the concrete
- **Silica Fume:** A byproduct of silicon metal or ferrosilicon alloy production, silica fume is a pozzolanic material that improves concrete strength and durability while reducing cement content.
- **Calcined Clays:** Calcined clay, such as metakaolin, are natural or a by-product of various industrial processes that can be readily available that it can be used as a partial substitute for clinker, resulting in reduced energy consumption and CO2 emissions, offering performance benefits and environmental advantages The incorporation of calcined clay also enhances the properties of the cement, such as improved durability and strength (Barbhuiya, S. et al., 2024)
- **Hempcrete:** A bio-composite material combined with concrete, making it an excellent choice for reducing carbon emissions and enhancing energy efficiency. Made from hemp fibers, lime, and water, Hempcrete sequesters carbon, significantly contributing to its carbon-reducing properties.

It is also a great option for increasing thermal performance while keeping energy consumption low. It is useful across several different climates as well.

- B. **Alternative Binders:** New binders that do not rely on Portland cement, such as:
 - **Geopolymer Binders:** Geopolymers are inorganic polymers formed by the reaction of aluminosilicate materials with alkaline activators. They offer high strength and durability with lower environmental impact compared to Portland cement.
 - **Calcium Sulfoaluminate (CSA) Cement:** CSA cement, also known as calcium sulfoaluminate cement or expansive cement, is an alternative binder that offers rapid strength development and reduced carbon footprint compared to Portland cement.
 - **Alternative Aggregates:** Alternative aggregates, such as recycled concrete aggregate, industrial byproducts, and natural materials like crushed volcanic rock or recycled glass, should be intended to be used to reduce the environmental impact of concrete production.
- C. **Low-Carbon Concrete Mixtures:** Engineers are optimizing concrete mixtures to reduce cement content, increase the use of supplementary cementitious materials, improve aggregate grading, and enhance workability and durability while minimizing carbon emissions. Recycled aggregates, sourced from demolished structures, offer an eco-friendly alternative, while locally obtained aggregates reduce transportation distances, further diminishing environmental impact¹ Innovations in concrete technology, leveraging chemical admixtures and additives, result in high-performance mixes requiring less cement content, thereby reducing the overall carbon footprint
- D. **Ready Mixed Concrete (RMC):** RMC provides opportunity for use of pozzolanas and slag in greater quantities while maintaining strict quality control. RMC plants are equipped with pollution control measures, reducing environmental

1 Developing a novel mix design methodology for slow hardening composite cement concretes through packing density approach (<https://www.sciencedirect.com/science/article/abs/pii/S0950061821021498>)

pollution from dust, noise, and water runoff. The precise batching and mixing process of RMC minimize material wastage, leading to cost savings and environmental benefits

- E. **Precast concrete elements:** Precast concrete can be used in the construction in the form of building structure elements which are assembled at site and made monolithic by pouring in-situ concrete. The products can be more sustainable than traditional construction methods due to factors such as reduced waste, lower energy consumption, and the use of recycled materials in some cases. Many precast concrete manufacturers offer products that contribute to Leadership in Energy and Environmental Design (LEED) certification and other green building rating systems due to their sustainable attributes, such as recycled content, regional materials, and low-emission production processes.
- F. **Ferrocement:** Ferrocement is a thin composite material made of cement mortar reinforced with closely spaced layers of continuous and relatively small-diameter wire mesh. Despite its relatively thin cross-section, ferrocement exhibits high strength and durability. The steel reinforcement provides tensile strength while the concrete matrix provides compressive strength, resulting

in a material that can withstand considerable loads and stresses. Ferrocement typically requires less material compared to traditional concrete construction methods due to its thin cross-section and efficient use of reinforcement. This reduces the overall environmental impact associated with material extraction and transportation. Ferrocement production typically requires less energy compared to traditional concrete production processes, resulting in lower greenhouse gas emissions. Additionally, the lightweight nature of ferrocement can reduce the carbon footprint associated with transportation and construction activities.

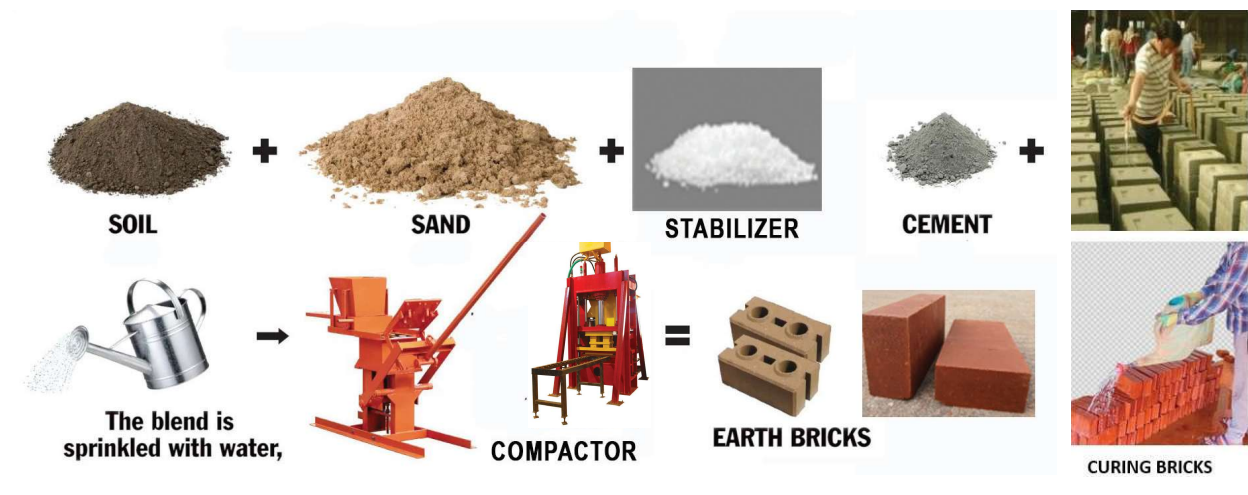
- G. **Carbonation-cured Concrete:** Carbonation curing is a process that accelerates the carbonation of concrete, converting CO2 into calcium carbonate and enhancing the material’s strength and durability while sequestering carbon.

7.4.2 Alternative Walls

1. Compressed Stabilized Earth Block/Brick (CSEB):

CSEBs are made from locally sourced soil, and sand or chemical soil stabilizers with lime/cement, offering an eco-friendly alternative by reducing dependence

Figure 42: Compressed Stabilized Earth block/brick Manufacturing



on scarce resources. CSEBs require less energy for production compared to traditional bricks or concrete blocks, as they involve minimal processing and transport of materials. Their earth-based composition contributes to carbon sequestration, further lowering their embodied carbon compared to materials like concrete and steel. CSEBs provide excellent thermal insulation, helping regulate indoor temperatures and reducing reliance on mechanical heating and cooling, resulting in energy savings and enhanced comfort. When properly stabilized², they exhibit durability, resisting weathering, pests, and fire, making them a resilient long-term building option. CSEBs align with green construction principles, offering a sustainable, resilient, and comfortable solution for the built environment.

2. Stone

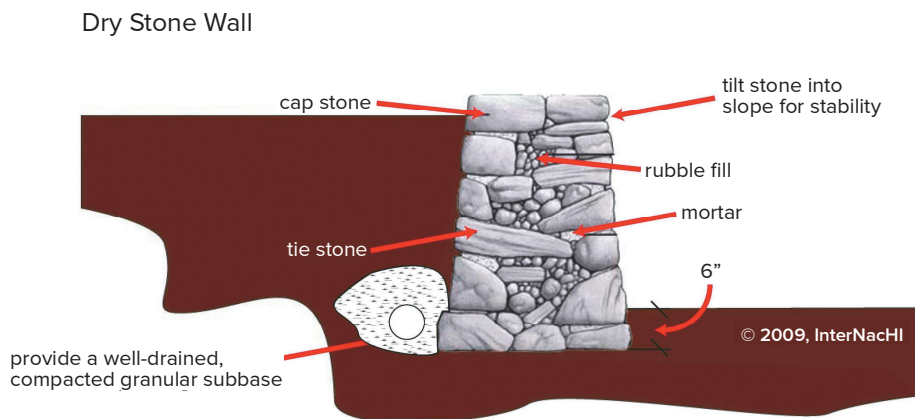
It is a traditional green and sustainable building material that has been used since ancient times. Detailed in the Nepal National Building Code (NBC

202:2015), its widespread application in construction is attributed to its natural abundance, durability, and minimal environmental impact. Locally quarried stone minimizes transportation emissions and reduces reliance on non-renewable resources. Its inherent strength and longevity make it resistant to weathering, pests, and fire, ensuring that structures require minimal maintenance and repair over time. Moreover, stone’s thermal mass properties enhance thermal comfort by regulating indoor temperatures and decreasing reliance on heating and cooling systems. As a natural material, stone also has a lower embodied energy compared to manufactured alternatives like concrete or steel, further bolstering its sustainability credentials.

3. Stonecrete

Stonecrete³, a concrete blend that incorporates cobble, pebble, crushed stone, or gravel aggregates, serves as a sustainable alternative to traditional concrete. By reducing the cement content—one

Figure 43: Stone as building material



(a) Stone as building material



(b) Stonecrete

of the primary contributors to CO₂ emissions—stonecrete helps lower the carbon footprint in construction. It also offers an efficient substitute for labor and resource-intensive dressed stone, supporting resilient building construction. The use of recycled aggregates, like crushed concrete or masonry rubble, further minimizes the demand for virgin materials and diverts waste from landfills. It's enhanced durability due to the strength of stone aggregates results in long-lasting structures that require minimal repairs, promoting sustainability in the built environment. With thermal mass properties that aid in temperature regulation and energy efficiency, and aesthetic versatility for architectural and landscaping uses, stonecrete supports greener construction practices and contributes to a resilient, sustainable built environment.

4. Adobe block

Adobe brick, also known as sun-dried brick, is a traditional, sustainable building material made from locally sourced earth, typically clay and sand, mixed with water and organic material like dung. Detailed in the Nepal National Building Code (NBC 204:2015), adobe brick requires minimal energy for production, resulting in a low carbon footprint. Its natural insulation properties help regulate indoor temperature and humidity, reducing reliance on artificial heating and cooling. Adobe bricks are a timeless, sustainable choice that integrates resource efficiency with environmental responsibility, harmonizing tradition with ecological principles.

5. Hollow concrete block (HCB)

HCBs are pre-cast concrete blocks with one or more large holes, made from cement, sand, and aggregates. Nepal Standard: 119/2042 specifies the minimum requirements for HCBs used in construction in Nepal. HCBs present several advantages in sustainable construction. While concrete production has environmental impacts, hollow blocks offset this by using less material and incorporating hollow cores that improve a building's thermal performance. Their durability and resistance to weather, pests, and fire reduce the need for frequent replacements, thereby

conserving resources and reducing waste. Many hollow concrete blocks also incorporate recycled materials, diverting waste from landfills and lowering their environmental footprint. Locally sourced and adaptable to various designs, they minimize transportation emissions and enhance construction flexibility. Though concrete production's impacts should be considered, hollow concrete blocks, used thoughtfully, support more sustainable building practices.

6. Rammed Earth

Rammed earth wall construction is a traditional and environmentally friendly method deeply embedded in Nepal's architectural heritage. Recognized in the Nepal National Building Code (NBC 204:2015, Clause 7.1.2), this technique uses locally available materials, including clay, sand, gravel, and stabilizers such as lime or cement, which minimizes transportation emissions and maximizes resource efficiency. Rammed earth walls offer exceptional thermal mass, naturally regulating temperature and humidity to provide excellent indoor air quality and thermal comfort. Known for their durability and low maintenance, rammed earth buildings provide sustainable, resilient solutions that honor Nepal's cultural heritage while promoting environmental responsibility.

7. Straw bale

Straw bale construction is a sustainable building method that utilizes tightly packed straw or hay bales. These bales offer excellent insulation, reducing energy consumption for heating and cooling. As agricultural waste products, they promote resource efficiency and reduce environmental impact. Straw bales are renewable, biodegradable, and often sourced locally, further enhancing their eco-friendliness. Additionally, they provide versatility in design and construction while adding aesthetic appeal to buildings. Overall, straw bale construction embodies sustainable building practices, offering energy-efficient, environmentally responsible, and aesthetically pleasing solutions for construction projects.

2 Three mode of stabilizers – physical, mechanical and chemical, More details refer Shrestha S & Watanabe I, 2016
3 Stonecrete Manual, Habitat for Humanity

8. Autoclaved cellular concrete (ACC) block

AAC blocks are gaining popularity as an alternative for wall construction in Nepal, especially in infill and partition walls following the Gorkha earthquake. The IS 2185: Part 3 code in India and NS 573 in Nepal outline the properties and permissible values for AAC blocks. Composed of cement, lime, sand, and aluminum powder, these blocks undergo autoclave curing, resulting in a lightweight cellular structure that reduces dead load and facilitates design optimization.

AAC blocks offer excellent thermal insulation, helping to regulate indoor temperatures and decreasing reliance on heating and cooling systems, thereby enhancing energy efficiency. They are also durable, fire-resistant, and resistant to pests and moisture, contributing to resilient and sustainable built environments with minimal maintenance needs. Additionally, their versatility allows for various applications, from load-bearing walls to partitions, enabling faster construction and reducing labor costs.

9. Brick and block products made up of recycled content

Figure 44: Sustainable Wall materials



(a) Rammed Earth Wall



(b) Hollow concrete block

Bricks and blocks can be produced using recycled aggregates like crushed concrete, reclaimed bricks, fly ash from coal plants, blast furnace slag, rice husk ash, and waste wood fiber. These materials create an environmentally friendly construction option that emphasizes resource efficiency and waste reduction.

Concrete blocks can incorporate materials such as fly ash which can replace up to 35% of cement,

and slag, which can make up 20-25% of the mix. This reduces the demand for virgin resources and enhances sustainability. Additionally, concrete masonry units with finished surfaces can eliminate the need for extra wall layers, saving on materials and energy. Options like sintered clays and glass blocks with recycled content further improve the eco-efficiency of construction practices.

10. Precast and prefab panels

Precast and prefab panels are sustainable wall materials that offer numerous environmental benefits. Manufactured off-site in controlled conditions, these panels minimize waste and energy consumption compared to traditional on-site construction methods. Their standardized designs optimize material usage, further reducing environmental impact.

Incorporating recycled materials into their production enhances their sustainability. Prefabricated panels provide improved insulation, which lowers energy consumption for heating and cooling. Their quick installation reduces construction time and labor costs while minimizing disruption to the surrounding environment. Additionally, precast and prefab

panels can be disassembled and reused, promoting circular economy principles and reducing waste generation. Overall, these panels support green building practices by offering efficiency, durability, and environmental responsibility in construction projects.

11. Cob walls

Cob walls represent a traditional, sustainable building method, especially suitable for areas with

abundant clay-rich soil. Made from a mixture of clay-rich soil, sand, straw, and water, cob walls offer significant environmental advantages and excel in thermal mass, naturally regulating indoor temperatures and humidity, which creates health and comfortable indoor space. Additionally, cob construction supports cultural preservation and community involvement, as it employs traditional techniques passed down through generations. (See Chapter 6 and 10)

12. Timber

Timber is a versatile and traditional building material used in both structural and non-structural applications. It features low embodied energy, is renewable, and can be reused or repurposed, offering a long lifespan in indoor environments. Timber's natural thermal properties provide insulation, enhancing indoor comfort. However, overharvesting can lead to negative environmental impacts, so it's recommended to source timber from sustainably managed forests, social agroforestry, or reclaimed materials. Proper seasoning and preservative treatment are necessary to protect timber from fire, moisture, termites, and other pests, with a focus on using minimal toxic chemicals based on specific applications.

13. Bamboo

Bamboo is a traditional, sustainable building material known for its eco-friendly qualities and versatility which offer a lower environmental impact than traditional timber. As one of the fastest-growing renewable resources, it has been widely used historically for shelters and structures. With the understanding of its physical and mechanical properties, bamboo is now seen as a viable engineering material for modern construction, compliant with standards such as Nepal's NBC 202:2015. With a remarkable strength-to-weight ratio that rivals steel, bamboo offers durability and structural integrity and can replace reinforced steel in tensile zones in certain applications and within limitations (National Building Code of India). Its natural flexibility supports a range of architectural uses, from frameworks to flooring and cladding. Additionally, bamboo sequesters CO₂ during growth, helping reduce greenhouse gas emissions. This combination of strength, renewability,

and environmental benefits makes bamboo an exemplary choice for sustainable building practices.

7.4.3 Mortar

Mortar is a construction material used to bind building blocks and fill gaps, commonly made from cement, sand, and water, with lime or clay as potential alternatives. It offers structural support, load distribution, and protection against moisture and pests, with variations in composition to meet specific strength and durability requirements. Incorporating sustainable alternative binding materials and recycled, or renewable aggregates as specified in 7.4.1.1 into mortar minimizes environmental impact by reducing resource use, energy consumption, and emissions typically associated with traditional mortar. Below are some sustainable mortar options:

- a) **Mud mortar:** Mud mortar is an eco-friendly, sustainable building material composed of locally sourced earth materials like clay, sand, and organic additives such as straw or dung. With minimal processing needs, ease of application, and non-toxic composition, it provides excellent thermal performance and breathability, enhancing indoor air quality and creating healthier spaces. Mud mortar offers significant environmental, social, and economic benefits compared to conventional mortars. Furthermore, its biodegradability allows it to return to the earth at the end of a building's life cycle, reducing construction waste.
- b) **Lime mortar:** Lime mortar is a sustainable choice in construction, made primarily from natural limestone, an abundant resource. Unlike cement-based mortars, lime mortar production generates significantly less carbon dioxide, making it an eco-friendly option. Its breathability allows moisture to escape from walls, reducing dampness and mold growth risk, which promotes healthier indoor environments. Lime mortar is also durable, recyclable, and highly compatible with historic structures, making it ideal for restoration and cultural preservation. These qualities position lime mortar as a green building material that supports environmental responsibility and long-term sustainability.
- c) **Cement mortar:** Portland cement mortar is widely used for constructing load-bearing masonry walls due to its strength and impermeability compared

to lime mortar. However, cement production contributes significantly to greenhouse gas emissions and high embodied energy. To make cement mortar more sustainable, various strategies can reduce its environmental impact:

- **Supplementary Cementitious Materials:** Replacing a portion of Portland cement with alternative cementitious materials specified in Section 7.4.1.1 can lower emissions while maintaining strength
- **Optimized Mix Designs:** Adjusting mortar composition to use only the necessary cement volume reduces resource use without compromising durability.
- **Locally Sourced and Recycled Materials:** Using locally available and recycled aggregates and binders minimizes transportation emissions and reduces the demand for new resources and diverts waste from landfills
- **Efficient Water Use:** Monitoring water consumption in mixing and application conserves water resource

Conducting a life cycle assessment evaluates the environmental impacts of mortar throughout its life cycle, guiding improvements for enhanced sustainability.

- a) **Surkhi –Lime pozzolana mortar:** Surkhi-lime pozzolana mortar is a traditional building material often used in construction, especially in areas where lime and surkhi (burnt clay) are abundant. This mortar combines lime, surkhi, and water, with pozzolanic materials like fly ash or volcanic ash added to enhance its properties. It offers improved workability, reduced shrinkage, and greater durability compared to pure lime mortar, as the pozzolanic materials react with lime to form additional binding compounds, resulting in a stronger mortar. Commonly used for masonry, plastering, and rendering, surkhi-lime pozzolana mortar supports sustainable building practices while preserving traditional construction techniques

7.4.4 Roofing Materials

Monolithic concrete slabs and CGI roofing are commonly used as roofing materials in Nepal but have poor thermal performance which is hot in

summer and cold in winter. Meanwhile, eco-friendly traditional roofing systems like slate, mud, and local tile roofing are declining in usage, putting vernacular roofing technologies at risk of extinction due to reduced patronage. When choosing roofing materials for a green building, it is essential to prioritize sustainability, resource efficiency, durability, and environmental impacts. In the case of concrete slabs and CGI roofing, adequate insulation should be added that helps reduce heat input from the roof. Applying insulation on the roof externally (with proper waterproofing) performs better. Some of the available options for roofing materials are:

- a) **Burnt clay tiles:** A traditional material still very suitable today, with quite good thermal properties. Although heavier than sheet roofs, their thermal mass is not great enough to store heat during the day and release it at night if a ventilated void is provided. They are relatively heavy and require a strong support structure. They are permeable to air through the gaps between the tiles.
- b) **Slate or Flagstone:** Slate or Flagstone is a natural material that has a low environmental impact. It is durable, fire-resistant, and requires minimal maintenance. Additionally, these materials are recyclable and can be salvaged for reuse. Slate has similar properties as clay tiles but somewhat reduced heat resistance depending on the thickness and the surface (brightness).
- c) **Thatch roofing:** While thatch roofing offers unique benefits and adds to the cultural heritage of many regions, its suitability for modern green building practices may depend on factors such as local climate, building codes, maintenance capabilities, and aesthetic preferences. It can be a sustainable option when properly managed and maintained, but it may not be suitable for all environments or building types.
- d) **Cool Roofs:** Cool roofs are designed to reflect more sunlight and absorb less heat than standard roofs. They are typically made from highly reflective materials such as white membranes, tiles, or coatings. Cool roofs can help reduce urban heat island effects and lower energy consumption for cooling.
- e) **Wood Shingles or Shakes:** Wood shingles and shakes are renewable and biodegradable

roofing materials. They are often made from sustainably harvested wood species such as cedar or redwood. While wood roofs require more maintenance than other materials, they can have a lower environmental impact when sourced responsibly.

- f) **Solar Tiles or Shingles:** Solar tiles or shingles integrate photovoltaic cells into the roofing material, allowing homeowners to generate electricity from sunlight. While initially more expensive than traditional roofing materials, solar roofs can provide long-term energy savings and reduce reliance on fossil fuels.
- g) **Vegetated (Green) Roofs:** Green roofs are covered with vegetation, which provides insulation, reduces stormwater runoff, and improves air quality. They can help mitigate the heat island effect in urban areas. Green roofs require proper structural support and waterproofing but offer numerous environmental benefits.

7.4.5 Surface Materials

Selecting surface materials in green building projects requires a focus on sustainability, durability, indoor air quality, and minimizing environmental impact throughout the material's lifecycle. Prioritizing materials that are resource-efficient and environmentally friendly not only contributes to healthier indoor environments but also reduces the overall ecological footprint of buildings. Indoor surface materials should allow water vapor diffusion with a low Diffusion resistance factor (μ) value. Key surface material options commonly used in green buildings include:

A. Floor and Floor covering:

- **Bamboo Flooring:** Bamboo is a rapidly renewable resource that grows much faster than hardwood trees. Bamboo flooring is durable, eco-friendly, and available in various styles and finishes
- **Linoleum Flooring:** Linoleum is made from natural materials such as linseed oil, cork dust, and wood floor. It is biodegradable, low in volatile organic compounds (VOCs), and available in a wide range of colors and patterns
- **Cork Flooring:** Cork flooring is a sustainable material known for its renewable nature and eco-friendly harvesting methods. Harvested from the bark of cork oak trees without harming the trees, cork production supports forest health and biodiversity while minimizing waste and energy use. Cork is also durable, ensuring a long lifespan that reduces waste from frequent replacements. Additionally, cork flooring provides comfort and health benefits, improving indoor air quality, making it a popular choice for eco-conscious consumers seeking environmentally friendly flooring options.
- **Reclaimed Wood Flooring:** Reclaimed wood from old buildings, barns, or other structures can be repurposed for flooring, adding character and warmth to a space while reducing the need for new lumber.
- **Natural Stone Flooring:** Stone materials like slate, granite, or limestone are durable, long-lasting, and available in a variety of colors and textures. Choosing locally sourced stone reduces transportation emission

B. External and Internal Wall finishes

- **Natural Plaster:** Natural plaster is made of natural ingredients like clay, sand, straw, and sometimes lime. It is non-toxic, biodegradable, and has a minimal environmental impact compared to conventional alternatives. Natural plaster effectively regulates indoor humidity, creating a healthier living environment and improving indoor air quality by absorbing odors and pollutants. Its excellent thermal mass properties provide effective insulation, helping to maintain comfortable indoor temperatures and promoting a healthy, comfortable building atmosphere. With its versatility, durability, and aesthetic appeal, natural plaster is an excellent choice for green building projects.
- **Lime plaster:** Lime plaster is a traditional and eco-friendly building material made from limestone (calcium carbonate) that is burned and slaked with water. It is non-toxic, breathable, and antimicrobial, promoting a healthy indoor environment. As it cures, lime plaster absorbs carbon dioxide, making

it carbon-negative over its lifespan. Its durability, flexibility, and resistance to cracking ensure long-lasting protection for surfaces. Additionally, its high pH level discourages mold growth, enhancing indoor air quality.

- **Clay plaster:** Clay plaster is being used for centuries in various cultures around the world. Made primarily from clay-rich soils, sand, and sometimes straw or other natural fibers. It is non-toxic, biodegradable, and has low embodied energy compared to synthetic alternatives. It regulates indoor humidity levels by absorbing and releasing moisture, creating a healthier and more comfortable indoor environment. It also has excellent thermal properties, providing natural insulation and helping to regulate indoor temperatures, which can contribute to energy efficiency and reduce heating and cooling costs. With its natural aesthetic, versatility, and durability, clay plaster is an attractive choice for eco-conscious builders.
- **Gypsum plaster (Plaster of Paris):** Although it may not be as eco-friendly as natural alternatives like lime or clay plaster, it can still contribute to green building when used responsibly. Made from gypsum, a naturally occurring mineral, it typically requires less energy to produce than cement-based materials. Gypsum plaster offers good fire resistance and can improve indoor air quality when combined with low-VOC additives. Its versatility and ability to be recycled or reused at the end of its lifespan help reduce waste.

C. **Cladding:** Some of sustainable cladding materials for protecting and enhancing building exteriors are:

- a. **Timber Cladding:** A renewable and biodegradable material, timber cladding adds natural warmth and insulation to building exteriors. Responsibly sourced timber can also capture and store carbon, reducing overall emissions.
- b. **Stone Cladding:** Stone is a durable, low-maintenance option that provides excellent thermal mass. Locally sourced stone cladding minimizes transport emissions and connects

buildings with the regional environment and aesthetics.

- c. **Wallpapers:** Eco-friendly wallpapers made from recycled or natural fibers can be a sustainable choice for interiors, especially when paired with non-toxic adhesives. They are available in diverse textures and colors, contributing to both design and indoor air quality.
- d. **Gypsum Board:** Often used for interior wall cladding, gypsum board is recyclable, lightweight, and effective for sound and thermal insulation. Gypsum's low embodied energy and recyclability make it a sustainable choice for green buildings.
- e. **Fiber Cement Board:** Combining cellulose fibers with cement, fiber cement boards offer durability, resistance to moisture, and minimal maintenance. They provide a fire-resistant alternative to wood and are often made with recycled content, supporting eco-friendly building practices.

Each of these cladding options supports green building goals, including durability, low environmental impact, and improved indoor environmental quality

D. Low-VOC Paints and Finishes

Conventional paints and finishes often contain volatile organic compounds (VOCs) that release harmful chemicals into the air, adversely affecting indoor air quality. Low-VOC or zero-VOC paints and finishes provide a sustainable alternative, designed to reduce or eliminate these emissions, thereby supporting healthier indoor environments and reducing health risks for occupants. In green building projects, all paints, coatings, adhesives, and sealants applied indoors or in non-ventilated spaces should contain zero VOCs or meet specified VOC limits suitable for human health, as detailed in Table 7.1. Compliance can be verified through Material Safety Data Sheets (MSDS) provided by suppliers and other certifications that confirm adherence to the permissible VOC levels outlined in the guidelines.

7.4.6 Building Fenestration Materials

- A. **Glazing:** Glazing, which refers to the transparent or translucent material used in windows, doors, and skylights, plays a crucial role in green and

sustainable building design. Opting for glazing systems with advanced insulation properties like low U-values and high solar heat gain coefficients (SHGC) can significantly reduce heating and cooling demands while maximizing natural daylighting. Materials sourced from recycled content or renewable resources contribute to sustainability, as do frames made from responsibly managed forests or recycled sources. Innovative technologies like dynamic glazing offer adaptability to changing environmental conditions, optimizing energy performance and occupant comfort. Thoughtful design considerations, such as proper orientation and shading strategies, further enhance daylighting while minimizing unwanted heat gain. By prioritizing glazing options that align with these principles, green buildings can achieve energy efficiency, occupant well-being, and reduced environmental impact throughout their lifecycle.

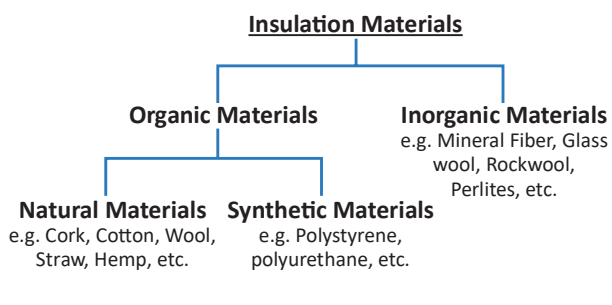
B. Door and window frames:

See Section 6.....

7.4.7 Climate Controls Materials

Green building practices emphasize a holistic approach that takes into account local climate conditions to maximize energy efficiency, minimize environmental impact, and enhance occupant comfort and well-being. Climate-controlling materials are those responsive materials that are engineered to respond dynamically to changes in temperature, humidity, light, or other environmental factors.

Figure 46: Classification of insulation materials



A. Thermal Insulation material

Thermal insulation materials, which are poor conductors of heat and have low thermal conductivity, are generally categorized into organic and inorganic groups based on their raw materials. Organic materials can be further divided into two subgroups: more environment-friendly natural materials and less environmentally friendly synthetic materials (see Figure 48).

- i. **Glass wool:** A popular, cost-effective insulating material made from silica sand, limestone, boron, recycled glass (about 70%) and acrylic resin. It is widely used in walls, attics, and floors, offering good thermal resistance (R-value). However, exposure to glass wool fibers can cause skin irritation, itching, eye damage, and respiratory issues, necessitating proper safety measures and barriers. Due to health concerns, its use has been restricted or banned in some countries, particularly in Europe.
- ii. **Mineral Wool (Rock Wool/Slag Wool):** It is a lightweight high embodied energy artificial material - Rockwool made from natural minerals, like basalt or diabase under high heat and Slag wool, is made from blast furnace/slag (the scum that forms on the surface of molten metal). Provides excellent fire resistance, thermal conductivity and soundproofing properties. It is denser and higher R-value and fire-resistant than Glass wool. However, similar to glass wool, it causes health hazards if handled without protective gear.
- iii. **Expanded Polystyrene (EPS) and Extruded Polystyrene (XPS):** These materials are light in weight and have very high R-value per unit thickness. While EPS has good moisture resistance and high compressive strength. XPS has low compressive strength and is not moisture resistant.
- iv. **Spray Foam Insulation:** It Expands to fill gaps, creating an airtight seal. It is more effective than many other types but also more expensive.
- v. **Cellular fibers:** Made from recycled paper treated with fire retardants, it's an eco-friendly option with good thermal properties
- vi. **Cotton:** Made from natural fibers or industrial waste from recycled cotton textile. It is also a good sound insulation and non-toxic, but high-

water absorption so should be protected by moisture-protected barriers.

- vii. **Natural wool:** Sheep and other livestock wool are a recycled and renewable material, making it an ideal choice for sustainable insulation materials. It does not contain harmful chemicals or emit toxic gases. It is also a fairly fire-resistant material, making it safe for use in the home.

B. Thermally Efficient Building Materials

Materials that naturally provide better thermal resistance or mass can help manage temperature variations:

- **Hempcrete:** A mix of fibers, lime, and water.
- **Straw Bale:** Straw bale walls have good thermal insulation properties. See section 7.4.2
- **Rammed Earth:** made of mud with good thermal mass properties, suitable for climates with significant temperature variations. See 7.4.2.
- **Aerated Autoclaved Concrete (AAC):** Lightweight concrete with good thermal and acoustic properties. (See 7.4.2.)
- **Cavity wall Insulation:** (See section 6.3.1.2)
- **Vernacular techniques:**
 - **Inverted Earthen Pot Insulation:** Shading the roof-top with inverted earthen pots is a traditional, easy, and cost-effective method to reduce solar gain. By virtue of the air trapped within these pots, they provide good insulation. Earthen pots painted white further reduce heat gain. Earthen pots are recyclable and locally or regionally available materials.
 - **Mud Layer:** In this traditional technique, a layer of mud containing excess clay or sand, free from gravel, stones, and other vegetable and foreign matter, is mixed with grass straw. This mixture is then applied over a sand-bitumen waterproofing layer, consolidated, and plastered with cow dung mortar.
 - **Brick Bat Layer:** This technique involves a layer of mortar with broken bricks as aggregate, using lime or cement as the binding matrix. A thick layer of brickbats provides good thermal insulation for the roof of the building.

C. Low-E (Low-Emissivity) Glass and Glazing Systems

- **Low-E Coatings:** These are applied to glass surfaces to minimize infrared and ultraviolet light passing through windows without compromising visible light. This helps keep heat out in the summer and inside during the winter.
- **Double or Triple-Glazed Windows:** Consists of two or three glass panes with air or inert gas (like argon) between them, providing better insulation.
- **Smart Glass:** Glass that can change its transparency or heat-blocking properties with electricity, allowing for dynamic control of light and heat in a building

D. Moisture and Air regulating material:

Moisture and air-regulating materials in sustainable buildings are essential for better indoor air quality, creating healthy and comfortable sustainable housing, and protecting buildings and building components from damage. These materials help maintain a comfortable indoor environment by controlling humidity levels and ensuring proper air circulation.

Materials such as clay plaster and wood naturally regulate humidity by absorbing and releasing moisture, while vapor-permeable membranes and breathable wall wraps prevent moisture buildup and improve the building envelope's performance. Insulation materials like sheep wool and cellulose also contribute by managing moisture without compromising thermal efficiency.

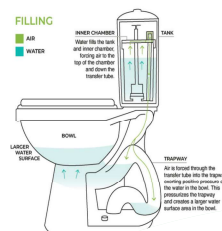
Airtight construction materials, such as sealants and prefabricated panels, minimize air leakage, while natural options like bamboo and compressed earth blocks promote passive ventilation. Additionally, smart ventilation systems, such as Mechanical Ventilation with Heat Recovery (MVHR), ensure proper airflow and prevent dampness.

These materials, when combined with climate-adapted designs and durable, low-carbon solutions, create resilient, comfortable, and environmentally friendly living space

Chapter 8

Water Efficiency

- >> Water Demand Assessment
- >> Water Efficient Approach
- >> Strategies for Water Conservation



8

Water Efficiency

Essential for the survival of humans, plants and animals, water has always been a finite resource. This has been becoming more acute due to rapid population growth and urbanization. Through the effective management and conservation of water, it is expected that water consumption can be reduced by at least 20% below baseline levels.

8.1 Water Demand Assessment

The water usage in buildings encompasses various activities, including drinking, cooking, bathing, washing, cleaning, maintenance, watering lawns, gardening, and flushing toilets. This collective need is referred to as water demand, typically measured in liters per capita per day (LPCD). According to NBC 208:2003, recommended water requirements vary for different types of buildings (see Annex 1). Water usage is influenced by factors such as climatic conditions, living standards, human behavior, water availability and quality, as well as the age group of the population. The following table presents the varying water requirements in SAARC countries.

As per this table, Nepal's urban per capita water demand is the lowest among SAARC countries

while its rural water demand is relatively higher. Daily water demand is calculated as follows:

$$\text{Total Daily Water Demand} = \text{No. of users} \times \text{LPCD}$$

8.2 WATER Efficient Approach

The design of buildings refers to both the initial design process before construction and during refurbishment. Water consumption can be reduced by up to 20-30% by efficient plumbing, use of rainwater, and reuse of greywater. Some of the key considerations for water conservation while designing buildings are as follows:

- Develop a water optimization design.
- Use water-efficient techniques and technologies.
- Water Optimization through reduction, reuse, and resource

8.3 STRATEGIES for Water Conservation

Water conservation is a process of prudent management that involves various techniques and technologies including water source protection, the use of alternative sources of water, reuse/recycling of water, and reduction in water consumption. These are some

Table 8: Water requirement standards in SAARC Countries

SN	Country	Urban	Rural	Source
1	India	135-150 LPCD	40-70 LPCD	NBC 2016
2	Bangladesh	100-150 LPCD	50-100 LPCD	Bangladesh National Building Code 2020
3	Pakistan	135-225 LPCD	40-70 LPCD	Pakistan Building Code
4	Sri Lanka	120-150 LPCD	60-100 LPCD	Sri Lanka National Water Supply and Drainage Board Guidelines
5	Nepal	100 LPCD	100 LPCD	NBC 208
6	Bhutan	100-120 LPCD	50-80 LPCD	Bhutan Building Code
7	Maldives	150-180 LPCD	80-100 LPCD	Maldives Building Code

Table 9: Water consumption

Use	%
Drinking	5%
Cooking	5%
Bathing	40%
Washing	20%
Flushing	30%
TOTAL	100

of the most sustainable solutions to address the growing challenges in water conservation. In green housing, efforts are made to reduce water consumption by at least 20%.

8.3.1 Reduction of water consumption

Reduction of water consumption can be achieved through the installation of water-saving fixtures and promoting changes in water usage behavior.

8.3.1.1 Use of Water saving fixtures

Water-saving fixtures play a crucial role in reducing water consumption significantly. There are several types of water-saving fixtures available in the market and it is important to make a prudent choice of them during the design phase. Some of the water-saving fixtures are listed below:

- **Low-flow toilets:** It is high-efficiency toilets that use less water per flush than traditional toilets.
- **Dual flush toilets:** It is a toilet having two flush buttons, allowing users to choose different amounts of water to flush. This design aims to reduce water usage by providing a smaller flush for liquid waste and a larger flush for solid waste.
- **Pressure-Assisted Toilets:** Uses pressurized air to enhance the flushing power, allowing for effective waste removal with less water. Typically uses 3 to 6 liters per flush and is highly efficient in clearing waste, reducing the need for multiple flushes.
- **Gravity-Assist Toilets:** Rely on the natural force of gravity and a siphoning action to remove waste. Modern designs are optimized to use as little as 4.8 liters per flush while maintaining effective waste removal.
- **Waterless toilets:** Composting Toilets and nano membrane toilets are waterless toilet that uses no water to flush the waste. Compost toilets decompose human waste into compost using aerobic processes. Similarly, nano membrane toilet operates under a heating system and converts human waste to water and ash.
- **Low-flow sink faucets:** These faucets reduce the amount of water used per minute without compromising the functionality that we expect from them.
- **Faucet aerators:** It is often found at the tip of modern water faucets. Aerators create a non-splashing stream and can reduce water usage by up to 30%.
- **Water-saving showerheads:** This uses air bubbles to reduce water pressure and hence reduce the consumption of water without compromising the user's expectation.
- **Tankless water heaters:** Tankless water heaters heat water instantaneously without the use of a storage tank. It uses less water and energy than tank models.
- **Pressure-reducing valves:** These valves regulate water pressure and can reduce water waste.
- **Recirculating pumps:** It keeps hot water circulating through the plumbing system, ensuring that hot water is available all the time as users turn on the tap.
- **Plumbing fixtures and fittings:** In the case of green buildings, the following performance of Plumbing fixtures (water closet and urinals) and fittings (faucets, showerheads, sprays, etc.) with correct water pressure required for the building to avoid water wastage (because of high flow rates in taps and showers) is recommended. Use orifice flange or pressure-reducing valves. Maintain uniform pressure restricted to 25-30 m/ head or 200Kpa.
- **Sensor-based fixtures:** This uses a sensor to detect changes and control the flow of water. It is touchless plumbing fixture that also reduces the risk of germs transfer via the fixture.
- **Water-Saving Appliances:** Appliances such as washing machine, dishwasher etc. use less water than hand washing without compromising the quality of the wash. Also, top-loading washing machines typically use 40% to 50% more water than front-loading washing machines even though there is no difference in the cleaning action. In addition, the appliances with ENERGY STAR-rated use less water than the normal ones.
- **Smart Irrigation Systems:** Irrigation using smart ways consumes less water without compromising its output. Sensor-based watering, Sprinkler, and dripping are the smarter ways of irrigation.
 - The watering schedules are adjusted using sensors that work based on weather conditions and soil moisture levels.

- A sprinkler is used to apply water in a manner similar to rainfall thereby using water judiciously.
- In drip irrigation, water is delivered directly to the roots of plants, reducing water waste.
- **Leak Detection Systems:** Smart leak detectors alert users to the leakage in the plumbing system.

8.3.1.2 Change the water use behaviors

Water use behavior is the way people use water in their daily life activities, and it can highly impact on water consumption. It can be influenced by many factors such as Culture, Socio-economic factor, Water scarcity, Cost of water, Awareness, Education etc. Some examples of water use behaviors that can significantly reduce consumption are:

- **Fix Leaks:** Check for and repair leaks in faucets, toilets, and pipes. Fixing leaks: Leaks can waste a lot of water over time, so it's important to check for and repair them regularly.
- **Shorter Showers:** Reduce the time you spend in the shower.
- **Turn Off Taps:** Don't leave water running or use a mug of water while brushing teeth, shaving. The flowing tap causes waste of water considerably.
- **Full Loads:** Using dishwashers and washing machines with full loads
 - Taking showers instead of baths
 - Washing a car/bike/vehicle less often
 - Choosing drought-tolerant plants
- **Timing:** Watering the garden in the morning or evening
- **Reuse:** Wastewater generated from vegetable cleaning, bathing, washing, water basin can be reused for gardening and cleaning purpose with or without treatment.
- **Multiple Use of Water:** There is a well-known approach called Multiple Use Water Schemes (MUS) that provides water for both domestic needs and high-value agricultural production, including livestock. It is low-cost and technique for optimum use of water. Overflow from tank is used for livestock and irrigation.

8.3.2 Rainwater Harvesting

Rainwater is one of the purest sources of water accessible from roofs and hardscapes in locations with regular or intermittent rainfall. One of the most effective methods to implement green efforts is to require rainwater harvesting for domestic use and groundwater recharge in all green housing programs. Rainwater is collected and stored for potable (after treatment) and non-potable applications such as toilet flushing, irrigation etc.

Rainwater harvesting is an old/traditional practice in Nepal. Collection of rainwater in ponds or vessels for future use or ground water recharge has been done for many years. In Kathmandu Valley, the traditional towns have ponds, which collect rainwater, feed the stone spouts and wells, and provide water for drinking and other domestic purposes as well as emergencies.

8.3.2.1 Basic Method of Rainwater Harvesting

Rainwater can either be harvested for instant use or future use, which suggest two different methods of harvesting i.e. storage system or recharge system respectively. It is essential to consider the design appropriate harvesting methods based on subsurface properties and intended use of water. Depending on the groundwater levels, solutions such as groundwater recharge can be explored for low groundwater levels, while rainwater storage systems can be considered for shallow groundwater tables. Similarly, the storage system is for instant use of water while recharge system adopted if the use of water is intended for future.

- a. **Rooftop Rainwater Harvesting:** This is rainwater storage system. Rainwater is collected from rooftops via gutters and downpipes and stored into a tank which can be instant use. The initial rainfall is usually discarded as it may contain dust, leaves, bird droppings, and the water collected afterward can be used following basic filtration.
- b. **Rain Gardens:** It is a recharge system. Rain gardens are good for managing stormwater and recharge groundwater. Rain gardens should be developed in low-lying areas where water naturally collects, soil should be of good

permeability for higher water absorption. The native shrubs, perennial plants enhance the water absorption capacity of the surface.

The rainwater harvesting system should be provided with the first flush mechanism to remove pollutants in the first few showers.

8.3.2.2 Assessment of Rainwater Availability

Calculate the potential rainwater capture based on local rainfall data and roof area. Estimate the seasonal variability of rainfall.

Calculating annual rainwater, harvesting potential from the roof of a house.

$$Q=A*R*C$$

Where,

Q = Potential Amount of rainwater harvesting

A = Catchment area

R = Average annual rainfall

C = Roof type-based Runoff coefficient. The runoff coefficient accounts for losses due to evaporation, spillage, etc.

8.3.2.3 Major components of Rainwater harvesting

Components of the rainwater harvesting system mainly include catchment and conveyance systems.

a. Catchment

The catchment is the simple surface that receives rainfall directly and contributes water to the system. The following are the general classifications of catchment based on:

- **Structure:** roof catchment and ground catchment
- **Nature of surface:** paved surface, unpaved surface and semi-paved surface

Different catchment areas have their runoff coefficient (Refer to Annex 2). It is the quantity of rainwater that is collected into the conveyance system and is very much instrumental in the design of the rainwater harvesting system.

b. Conveyance system

Conveyance systems include gutters and downspouts that direct water flow from the catchment area to the storage or recharge area.

Properly designed conveyance systems can divert more than 90% of the rainwater that falls over the catchment area, mainly the roof.

b.1. Gutter: Gutter is the first component of the conveyance system provided at the edges of the CGI roof. It collects water from the roof and conveys it into the downspout. The gutter can be semi-circular or rectangular and made up of galvanized iron or PVC. The rectangular gutter is commonly used compared to the circular one.

b.2. Downspout: Downspout is a piping network that transports water to storage. Normally PVC and HDPE pipes are used for delivery. The size of the pipe depends upon the rainfall intensity and roof surface area; however, inadequate number and size of downspouts causes overrunning/loss of rainwater. The following table represents the size of the downspout:

c. Rainwater Storage

Rainfall varies temporally and spatially. In Nepal, 80% of the rainfall occurs within 4-5 months which may require a huge investment to collect the entire potential amount of rainfall. Sometimes space may not be available for the huge tank. Thus, the design of storage is further challenging in the case of Nepal, and it should be estimated prudently. The design of storage is mainly governed by the following factors:

- Rainfall intensity pattern
- Run-off coefficient of catchment
- Water demand
- Space availability
- Fund availability

Sizing the rainwater storage tank can be done using the monthly water demand method. In this approach, the total water demand during the dry period and the total potential for rainwater harvesting are calculated. If the water demand exceeds the available rainwater collection, the maximum volume of rainwater that can be collected is used as the required storage volume. However, if the rainwater collection exceeds the demand, the water demand is taken as the required storage volume. (See Appendix 9: Sample calculation for rainwater harvesting design)

Table 10: Sizing of gutter for various catchment areas.

Type of Gutter	Roof Area (Sqm)	Gutter size (mm)
Half-round	25	Dia 100
	35	Dia 100
	50	Dia 100
Molded (Rectangular)	50	Depth 100* Width 75
	90	Depth 125* Width 100
		Depth 150* Width 125

Table 11: Sizing of rainwater pipes for roof drainage.

Dia of Pipe (mm)	Average rate of rainfall in mm/h					
	50	75	100	125	150	200
	Catchment Area (m2)					
50	13.4	8.9	6.6	5.3	4.4	3.3
65	24.1	16.0	12.0	9.6	8.0	6.0
75	40.8	27.0	20.4	16.3	13.6	10.2
100	85.4	57.0	42.7	34.2	28.5	21.3
125	-	-	80.7	64.3	53.5	40.0
150	-	-	-	-	83.6	62.7

source: NBC 208:2003

d. Recharge system

Groundwater aquifers can be recharged by various methods ensuring percolation of rainwater into the ground instead of draining away. Commonly used recharging methods are as follows.

- **Recharging of borewells/dug wells:** Rainwater collected from the rooftop of a building is diverted through to a borewell. It is passed through a settling or filtration tank so that the filtered water will be recharged.
- **Recharge pits:** Recharge pits are small, masonry-walled pits with weep holes, designed to recharge groundwater. It is covered with perforated lids and filled with filter material. The size pit depends upon the catchment area, rainfall, and permeability of soil. Typically, 1-2 meters wide and 2-3 meters deep, are ideal for refilling shallow aquifers for small dwellings.
- **Recharge trenches:** Recharge trenches are constructed in areas with shallow impervious soil. The trench is filled with porous materials

like pebbles, rocks, or brickbats. Borewells may be installed within the trench to enhance percolation. The length of trench depends on the runoff quantity, and it is typically 0.5–1.0 m wide and 1.0–1.5 m deep. This method is ideal for smaller homes, parks, playgrounds, and roadside drains.

8.3.3 Water Source Protection

Water source protection is the safeguarding of water sources i.e. lakes, rivers, or underground aquifers from potential contamination and overuse. Watershed Management ensures that water sources remain clean and abundant by controlling land use and reducing pollution in the surrounding areas. Implementing erosion control, reforestation, and sustainable agriculture practices helps maintain the natural filtration process.

- **Enforcement of regulatory instruments:** Develop and Enforce regulatory instruments such as pollution control laws, land-use planning, and sustainable water management policies to

protect water sources. Regulate proper treatment of industrial waste that reduces pollutants like chemicals, heavy metals, and pesticides from entering water sources.

- **Source protection chamber:** Provide a masonry and concrete chamber or platform to protect the source from contamination from its immediate surroundings.
- **Fencing:** Fences built around the water source precisely mark the inner protection zone and prevent animals and people from entering, defecating or destroying installations. Fencing is mainly applied for springs, as they are more susceptible to superficial contamination. However, shallow wells may also need protection zones. It is advised to use barbed wire, solid hedge of bushes or solid wall for fencing.
- **Buffer Zones:** Establishing buffer zones around water bodies (rivers, lakes, etc.) with vegetation or natural barriers to filter out pollutants before they reach water sources.
- **Pollution Prevention and Control:** Ensure that solid waste is not landfilled or fecal sludge / wastewater is not disposed of near to the water source, as it can leaching into and contaminate both surface and underground water source.
- **Septic tank Management:** Promote standard septic tank and retrofit the existing improper septic tank to protect leakage of wastewater into ground water.
- **Sustainable Land Use Practices:** Encourage sustainable farming, forestry, and urban development to avoid overuse or pollution of land and water resources. Promote organic farming techniques and agroforestry and reduce pesticide and chemical fertilizer use.
- **Plantation:** Plantation of shrubs and trees in the catchment area enhances soil stability and improves infiltration and boosts the moisture retaining capacity of soil. This helps reduce surface runoff, erosion, landslide risk while promoting higher water source recharge rates. The selection of shrub species, planting methods, and integration with other measures should be carefully tailored to local conditions.

- **Water Ponding and trenching:** Promote natural recharge ponds, trenching and check dams to increase infiltration, to reduce surface flow velocity and to minimize the landslide/erosion.

8.3.4 Water Storage

Availability of water storage provides significant benefits for a building by reducing the strain on water supply and providing a continuous water supply. Water storage also conserves the potable water for the building. Water can be stored in a non-corrugated structure. The provision of water storage also reduces the dependence on a motorized system and energy consumption. Considerations to be considered while developing water storage

- Use construction techniques that minimize soil erosion, water pollution, and habitat destruction. Employ erosion control measures such as silt fences and sediment basins.
- Design storage structures to blend with the natural landscape. Use natural materials and colors that match the environment. Incorporate landscaping around storage facilities to enhance visual appeal.
- Utilize gravity storage to minimize energy consumption. Gravity-fed systems do not require continuous energy input. Gravity storage provides a reliable water supply during periods of high demand or when renewable energy sources are intermittent (e.g., cloudy or windless days).
- In the gravity water storage system, water storage be placed on an elevated area or on the rooftop of the building through gravity system as per local plumbing standard.
- Smaller tanks are easier to screen with natural features and landscaping, reducing visual impact. Hence it would be wise to opt for multiple smaller tanks rather than one large tank as they offer operational flexibility, allowing for maintenance without disrupting the entire system.

By implementing these strategies, water storage methods can be designed to minimize environmental impact, maintain aesthetic quality, and ensure efficient, reliable operation using renewable energy sources.

8.3.5 Water Treatment

8.3.5.1 Water quality

The quality of water is as crucial as its quantity, and often even more. Therefore, it is imperative to evaluate drinking water quality in line with the physical and chemical standards established by Nepal Drinking Water Quality Standard (NWQS) (See Annex 3).

8.3.5.2 Treatment system

Before deciding on the water treatment system, the following considerations should be made:

- **Source-Based Treatment:** Conduct thorough water quality assessments to determine the contaminants present in the water source. Design the treatment process based on the source type (groundwater, surface water, or rainwater) and the specific contaminants identified during the assessment.
- **Environment-Friendly Groundwater Treatment:** Nature-based treatment systems like aeration, and sand filtration are highly recommended, which do not require chemicals or high energy input.
- **Hierarchy:** Water treatment can be done centrally and at the household level. Unless the entire water supply system is ensured that there is no cross-contamination, household water treatment cannot be skipped.

Stormwater Management

In the site's natural state, most stormwater would infiltrate and be absorbed by the vegetation and soft, open ground. However, as water flows along hard, paved surfaces the water can no longer infiltrate which increases the flow rate and quantity of stormwater being released from a site. This can cause or exacerbate flooding and the associated damage, especially in properties near rivers. Methods of capturing, retaining, and filtering stormwater on-site and releasing it slowly to municipal or ecological systems should be incorporated into the design of the building site and landscaping. This

is also explained in the previous chapters as well. (Sustainable Urban Drainage Systems).

On-site strategies for stormwater management, which can be designed include (designed by the calculated amount of stormwater for average rainfall and storm events):

- **Permeable paving:** Increased permeable paving and surfaces which allows stormwater to infiltrate the ground.
- **Infiltration pits/soak pits:** These are usually excavated pits that are packed with coarse aggregate where water is directed to a specific permeable portion of the site where it is detained and slowly infiltrates the ground.
- **Green roof:** Designing a green roof where the roof of a building is planted with low-maintenance vegetation. Green roofs retain and filter rainwater thereby releasing cleaner water more slowly.
- **Screens and traps:** When placed on-site at a point in the stormwater system before water is released from the building site, this help to reduce the amount of solid particle pollution, grease, and oil released into the stormwater system which can clog pipes and harm rivers and wetlands and their wildlife. This can be especially important in vehicle parking lots, vehicle mechanic workshops, and petrol stations where there is often a high concentration of toxic oils present on the paving surfaces.

8.3.7 Landscape water conservation

Landscaping has been explained in detail in previous sections. In most cases landscapes consume considerably more water which can be saved through proper design, irrigation, use of technology, proper selection of plant species, selecting soil quality and irrigation control system. Judicious and efficient irrigation practices (like using drip irrigations and sprinkler methods) and appropriate planting can reduce the use of irrigation water by 50%–70%. Planting native species promotes ecological balance and enhances water quality.

Chapter 9

Waste Management

- >> Sanitation Service Chain
 - >> Solid Waste Management
 - >> Construction Waste Management
 - >> Health Care Waste Management
 - >> Wastewater Management
 - >> Environment-friendly household technologies
-



9

Waste Management

Waste generation is unavoidable and is generated from every human activity but it needs to be managed properly. The U.S. Environment Protection Agency (EPA) has developed a Waste Reduction Model which suggests management practices, including source reduction, recycling, composting, anaerobic digestion, combustion and landfilling. The most sustainable way of waste management is to link with the circular economy. Unlike the traditional linear economy, a circular economy aims to minimize waste and make the most of available resources. Key principles of a circular economy include:

1. **Design for Longevity:** design products to be durable, repairable and easy to reuse.
2. **Keep Products and Materials in Use:** repair, refurbish or reuse the products and recycle or upcycle into new products.
3. **Minimize Waste:** reduce waste by keeping resources in continuous use.
4. **Use Renewable Resources:** prioritize the use of renewable or biodegradable materials.

Waste segregation at the source is a fundamental step in waste management (SWM). It involves separating waste into different categories, such as biodegradable and non-biodegradable, recyclable, non-recyclable, hazardous etc. Waste segregation at the source can help:

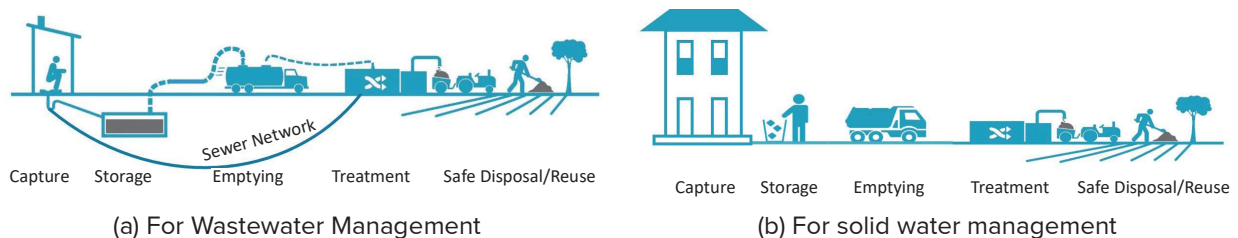
- **Reducing waste:** Reducing the amount of waste that needs to be disposed of in landfills
- **Recovering recyclables:** Making it easier to extract recyclable materials
- **Reducing occupational hazards:** Reducing the risk of hazards that can occur during waste separation

9.1 Sanitation Service Chain

Various types of waste are generated from buildings: solid waste, wastewater, hazardous waste, and construction waste both during construction and after occupation, all of which need to be managed properly.

- During construction: manage construction waste properly to be reused and promote the use of environmentally friendly building materials such as non-virgin, renewable and recyclable materials to help reduce the use of non-renewable resources
- During occupation: managing solid waste properly by the development of garbage recycling programs, organic waste composting, hazardous waste management, conversion of waste to energy and finally proper management of wastewater and its disposal.

Figure 47: Sanitation Service Chain



The entire sanitation service chain must be in place and functioning for proper waste management. The sanitation service chain is a series of processes that ensure the safe management of waste. The chain includes the following steps:

- **Capture:** The initial collection of waste
- **Containment:** The keeping of waste in a secure location
- **Emptying:** The removal of waste from its containment
- **Transport:** The movement of waste to a treatment or disposal site
- **Treatment:** The process of making waste safe for reuse or disposal
- **Safe reuse or disposal:** The final step in the chain where waste is either reused or disposed of safely

The sanitation service chain is a complex system. All the steps are interlinked and a weakness in one link can affect the entire chain. For example, if solid waste isn't collected or processed, it can end up in open drains, limiting their capacity to handle rainwater runoff.

9.2 Solid Waste Management

Solid waste refers to any non-liquid and non-gaseous waste. Waste is commonly classified as biodegradable, non-biodegradable and other waste based on its nature. In Nepal's cities, around 4,900 tons of municipal solid waste are generated daily. However, it is estimated that less than half of this waste is collected from urban areas (World Bank, 2020). A waste management baseline survey reveals that, on average, each municipality collects approx. 6.1 metric tons of waste per day, which totals approximately 1,787 metric tons of waste collected daily across urban areas in Nepal. (CBS Nepal, 2021). The estimated daily per capita waste generation of Nepal is approximately 0.30 kg and is lower than that of India (0.52 kg), Bhutan (0.52 kg) and Sri Lanka (0.34 kg) and similar to Bangladesh (0.28 kg) (World Bank, 2020).

9.2.1 Biodegradable Waste Management

Biodegradable waste refers to organic materials that can naturally decompose over time through the

action of microorganisms. This type of waste typically includes food scraps, garden waste, paper, wood and other materials that originate from plants or animals. Out of total waste generation, organic waste shares 56% (World Bank, 2020) while household waste consists of 66% organic (ADB Nepal, 2013). Biodegradable waste is safely managed through composting and digestion technologies.

9.2.1.1 Biodigester

Bio-digestion is an anaerobic process that produces biogas, compost and water. A biodigester is an airtight container that facilitates the anaerobic digestion of biodegradable waste. It produces biogas which are collected at the top of the container. The digested slurry, called digestate, is discharged from its outlet which is then dried and used as compost. The digestate is rich in organic nutrients, almost odorless and pathogens are partly inactivated. The hydraulic retention time (HRT) of biodigester should be at least 15 days in hot climates and 25 days in temperate climates. Normally, biogas reactors are operated at a mesophilic temperature range of 30 to 38 °C.

9.2.1.2 Composting

Composting is a technique that turns, by an aerobic process, organic waste into a nutrient-rich material called compost which is used in agriculture as a soil stabilizer. Under favorable conditions, microorganisms decompose biodegradable waste. It is a sustainable practice that can reduce waste volume, eliminate pests and create beneficial material. The entire composting process takes 3-6 months to complete. It works best with a balance of green (nitrogen-rich) material, brown (carbon-rich) materials, air, water and temperature. Design criteria for composting are CN ratio: 25-30:1, Temperature pH value: 6.5-8, Moisture content: 40-65% temperature: 55-60° C (Mishra R.V., 2003).

The size of particles and the pile itself affect airflow, water retention and microbial activity in composting. Smaller pieces increase surface area, allowing microorganisms to break down material more efficiently and larger particles improve air and water flow by reducing compost density. A balance of small and large particles optimizes compost density and porosity. There are a few popular techniques of composting such as,

a) Pile (Conical/Winrow) composting

Pile composting is a simple method that requires periodical turning for proper aeration. It is conical and windrow in shape and useful for both household and community scales. For a larger volume of waste, a windrow is preferable. The ideal size of the pile is 1.2-1.5 m in height and 1.5-4 m at the base. However, its length can be extended as needed, depending on the volume of waste and the availability of land. A porous base is provided to improve the drainage system, with a perforated pipe of diameter 110 mm minimum, a network beneath it to collect leachate.

b) Container composting

Container composting is a process of turning organic waste into compost using a container. Typically, it is done by using either a bin or a box chamber. The containers have holes in the walls to allow air circulation inside. Bin composting is usually designed for household use, while box composting is meant for processing larger amounts of waste. The ideal size of the box composting is 1 cubic meter. It is recommended to have a dimension of aerated box chamber 1-1.5 m wide, 1-1.2 m high and 2-3 m long to make the composting process easier and effective. In the case of higher depth and

length, it may become challenging to turn waste and manage the overall operation. Higher depth causes a problem for proper aeration.

In Nepal, plastic compost bins are commonly available with a normal size offering a 60-100 liters capacity.

c) Pit composting

It is a traditional method widely used in rural settings at a household scale. Normally the size of the pit is 1-1.5 m wide, 1 m high and 2-3 m long.

d) Vermi composting

It is a method that uses earthworms for composting organic waste. Earthworms can consume practically all kinds of organic matter and waste equal to their body weight per day, e.g. 1 kg of worms can consume 1 kg of organic waste every day. It excretes as compost which is rich in nutrients. A moist compost heap of size 2.4 x 1.2 x 0.6 m can accommodate more than 50,000 worms. Worms cannot survive in high temperatures and waterlogged conditions. Worms require dark environments for their higher activity.

Figure 48: Methods of Pile composting



a. Window Composting



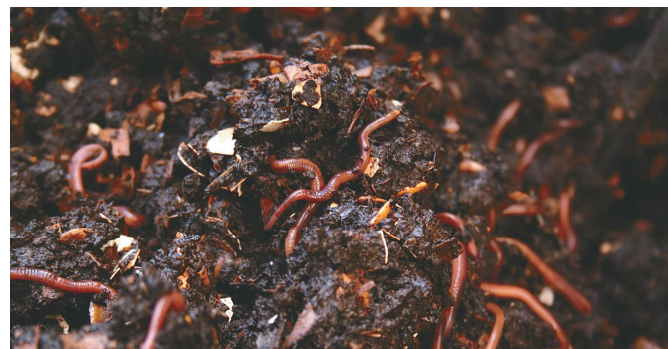
b. Bin Composting



c. Box Composting



d. Pit Composting



e. Vermi Composting

9.2.2 Non-degradable waste management

Non-degradable waste refers to materials that cannot be decomposed by natural processes. This type of waste typically includes metal, plastic, glass, electronic waste, hazardous waste etc. Out of total waste generation, non-degradable waste shares 44% (World Bank, 2020) while household waste consists of 34% (ADB Nepal, 2013). Municipal waste consists of 16% glass, 13% plastic, 8% paper, 3% textile, 3% metal and 1% other (World Bank, 2020).

Non-biodegradable waste is further classified into reusable, recyclable/up cyclable, non-recyclable, construction, and hazardous. Non-biodegradable waste is safely managed mainly through the following methods:

- **Reuse:** This involves finding new applications for waste/discarded material, without changing the original form or intent. Reuse of shopping bags, water jars, bottles of various drinks etc. This is the easiest way to manage waste.
- **Upcycling:** Upcycling is the art of transforming waste/discarded materials from their current state into new or products with a new purpose. It does not consume energy in the process. This is the most preferred process among creative individuals. Use of a jerrycan, bucket, water jar as a flowerpot; carpet as door mat; vehicle tyres as shit and table are a few examples of creative use of waste.
- **Recycling:** Recycling is the process of collecting and reprocessing materials that would typically

be discarded as waste and transforming them into new products. This helps to reduce pollution and conserve natural resources benefiting communities. It differs from upcycling in the consumption of energy during the process. For example, making water bottles, toys, bags, and ropes from plastic waste.

- **Incineration:** Incineration is a process where waste/discarded materials are burned at high temperatures in a controlled environment (called an incinerator) to significantly reduce their volume and mass (up to 95%). The process often generates heat that can be used to produce electricity, making it a form of “waste-to-energy” technology. However, concerns remain regarding potential air pollution from emissions produced during incineration if not properly controlled.
- **Landfill:** A landfill is a designated area where waste/discarded materials are disposed of in a controlled manner, typically by burying it in layers designed to minimize environmental contamination and protect groundwater through proper management and monitoring; it is considered a last resort in waste management due to its potential environmental impacts. As a part of sustainable management, these landfills can be operated to produce methane gas from decomposition and use it as an energy source. This method is primarily adopted to manage waste typical which cannot be reused or recycled.

Figure 49: Example of upcycling of unused tyres



9.3 Construction Waste Management

Building construction activity produces large quantities of waste and diverting it to landfill sites is becoming a major challenge. However, many construction waste materials (bricks, concrete, steel, wood, stone etc.) are reusable. It is often sorted and reused or sold to scrap vendors. It is essential to develop an effective construction waste management plan as a part of construction management. An effective construction waste management strategy should focus on aspects for ensuring proper disposal.

- a. **Waste Reduction:** Careful planning and accurate measurements are essential to optimize material use and prevent unnecessary waste. Whenever possible, it is beneficial to use prefabricated components that are made off-site which helps reduce on-site waste and ensures more efficient use of resources.
- b. **Segregation:** It is required to sort the waste materials every day or week right at the construction site, making it easier to recycle. For this, workers should be trained regularly.
- c. **Tracking and Reporting:** It is important to regularly track the amount of waste produced and managed. Accurate record-keeping helps to evaluate how well the strategy is working and identify areas for improvement.
- d. **Improvement Plan:** Periodic reviews are necessary to know about the progress and improve waste reduction and recycling practices.

9.4 Health Care Waste Management

Healthcare waste can contain microorganisms, including drug-resistant microorganisms that can infect patients, health workers, and the public. According to the WHO estimation, among the total amount of HCW generated, 80% is general HCW, 15% is pathological waste and infectious waste, 1% is sharp waste, 3% is chemical or pharmaceutical waste and less than 1% special waste such as radioactive or cytotoxic waste, pressurized containers or broken thermometers and used batteries. Thus, a very less amount of HCWs is hazardous if it is properly managed. However, HCW is often not separated into hazardous or non-hazardous waste making the quantity of hazardous waste much higher.

The Ministry of Health (MoH) report 2003 reveals that the HCW generation is 1.7 Kg/person/day. Out of which, 26 % of the waste is hazardous. In the Nepalese context, the categorization should entirely depend on the nature of healthcare institutions and the availability of treatment techniques and technology, considering the geographic and climatic variation of the country. Based on the amount and categories, it is recommended that the non-risk HCW should not be mixed with other HCW. Non-risk HCW should at least be separated into bio-degradable and non-biodegradable waste. Hazardous HCW should be separated into at least into six categories as follows:

- Pathological Waste
- Infectious waste
- Sharp waste
- Cytotoxic waste
- Pharmaceutical waste
- Other hazardous waste

Healthcare waste management (HCWM) is the process of handling and disposing of waste generated from healthcare institutions to prevent potential health risks and environmental pollution. It's an essential part of infection prevention practices and helps to protect the patients, staff, and the community. The following basic steps are considered essential for proper waste management:

- Waste minimization
- Waste segregation
- Waste collection and storage
- Waste transportation
- Waste treatment and disposal

9.5 Wastewater Management

Wastewater refers to the liquid waste produced from various human activities such as drinking, cooking, washing, cleaning, and bathing. It is estimated that approximately 80% of the total water consumed ultimately becomes wastewater. This highlight treated wastewater as a valuable resource, and its reuse supports the circular economy model of wastewater management, significantly reducing the demand for potable water. However, it is essential to ensure proper treatment before wastewater

can be safely reused or discharged back into the environment. The treatment process should be informed by factors such as the type of wastewater, the intended use of the treated water, land availability, and the necessary effluent standards. Generally, wastewater is categorized into grey water and black water.

- **Grey water** – Grey water refers to wastewater that is generally free from fecal contamination, primarily generated from activities such as washing, cleaning, bathing, and brushing. It constitutes the largest portion of total wastewater production, accounting for approximately 50-80% (Sandec, 2006).
- **Black water** – In contrast, black water is wastewater that contains fecal contamination, typically originating from toilets. It poses a significant risk to public health and the environment if not properly treated, as it can carry harmful pathogens. In households, black water comprises about 10-30% of total wastewater production.

Typically, a simpler treatment system is employed for processing greywater, whereas black water necessitates a more advanced level of treatment. The treatment process must adhere to national

effluent quality standards. Wastewater is generally treated through both natural and electromechanical systems. For small-scale wastewater treatment, nature-based systems are often adopted, while electromechanical methods are used when required for larger scale. Furthermore, wastewater with a higher concentration of pollutants demands more complex treatment methods.

9.5.1 Biological Treatment System

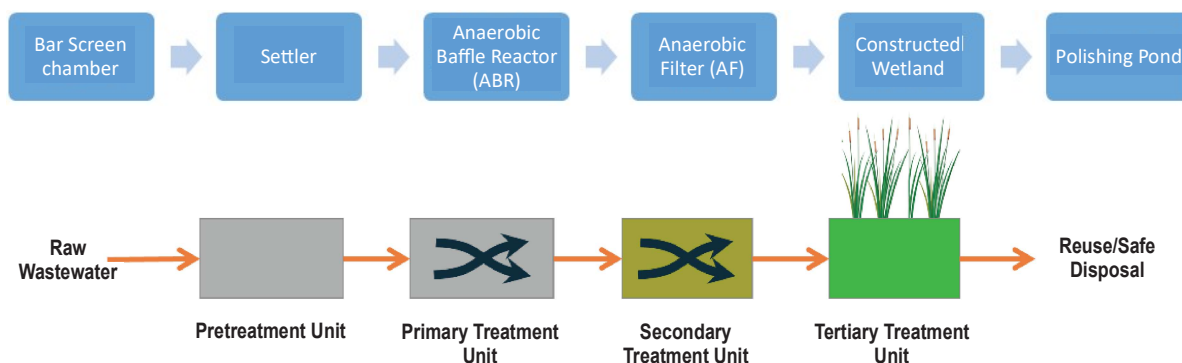
The biological wastewater treatment system utilizes natural forces and processes to efficiently treat wastewater to specified standards. Its popularity has surged, especially in developing nations, due to its cost-effectiveness in both construction and operation. The advantages and disadvantages of the biological treatment system are outlined as follows.

Natural treatment systems are site-specific, influenced by factors such as treatment goals, availability of space and other site characteristics. A biological wastewater treatment system comprises several essential components: a Bar Screen, Settler, Anaerobic Baffle Reactor, Anaerobic Filter, Constructed Wetland, and Polishing Pond. These components work together, utilizing natural forces and processes to effectively treat wastewater sustainably and efficiently.

Table 12 : Advantages and disadvantage of the biological treatment system

Advantages	Disadvantages
1. Low operation and management cost	1. Requires larger land area
2. Long operational lifespan	2. High initial investment
3. Basic training is enough for operation	3. Cannot treat toxic pollutant
4. Highly stable sludge	4. Low operational flexibility

Figure 50: Schematic diagram of biological waste treatment system



The biological treatment system is mainly adopted for rural areas where the volume of wastewater is low, electricity is not available or/and availability of electromechanical spare parts are challenging. This system is especially effective for treating non-toxic wastewater, as the presence of toxic substances can impede microbial activity. Additionally, since it depends on microbial processes, the system operates more efficiently in warmer climates.

9.5.2 Electro-mechanical Treatment System

The treatment system uses a range of electromechanical components, including pumps, conveyors, rotating screens, and aerators. These units are systematically organized to achieve the desired end products. In contrast to biological systems, the mechanical system operates on electricity but occupies a relatively small footprint. Figure 51 highlights the essential components of the mechanical wastewater treatment system that include a screen, grit chamber, screw press, aeration tank, clarifiers and a sludge digester, among others. The advantages and disadvantages of this system are given in Table 12.

As the mechanical treatment systems require less space, it is especially beneficial in urban areas where land is limited and costly. Also, mechanical systems are more suitable for wastewater containing toxic chemicals. Thus, they are commonly used to treat industrial wastewater.

9.6 Environment-friendly household technologies

The environmental-friendly household technologies are a fully nature-based and sustainable approach to waste management. It operates without the use of external energy, relying entirely on natural processes. Twin pits, Dry Ecosan, Biogas digesters and septic tanks are commonly used technologies in Nepal. Septic tanks are more suited to urban areas, while the other technologies are suitable for in rural settings.

9.6.1 Twin pit

This technology consists of two alternating pits connected to a pour-flush toilet. Wastewater, primarily from the toilet, is collected in these pits and allowed to gradually infiltrate the surrounding soil. Once one pit is filled, the other is used. Over time, the solids in the first pit are adequately dewatered and composted, allowing for manual removal with a shovel for reuse as compost. This alternating system enables the sludge in one pit to decompose and dry out while the other pit is in operation, providing valuable nutrients for crops.

9.6.2 Dry Ecosan

This system is similar to twin pit technology, but the chamber is constructed above the ground and no water is used for flushing. Urine and feces are collected separately through a specially designed

Table 13 : Advantages and Disadvantages of Electromechanical System of Waste Management

Advantages	Disadvantages
1. Land requirement is less	1. High operation and maintenance cost
2. Less impact by climatic factors	2. Possibility of noise
3. High operational flexibility	3. Require electricity and chemicals
4. High treatment consistency	4. Require skilled operator

Figure 51: Schematic diagram of Electro-mechanical Treatment System



Figure 52: Schematic sketch of twin pit

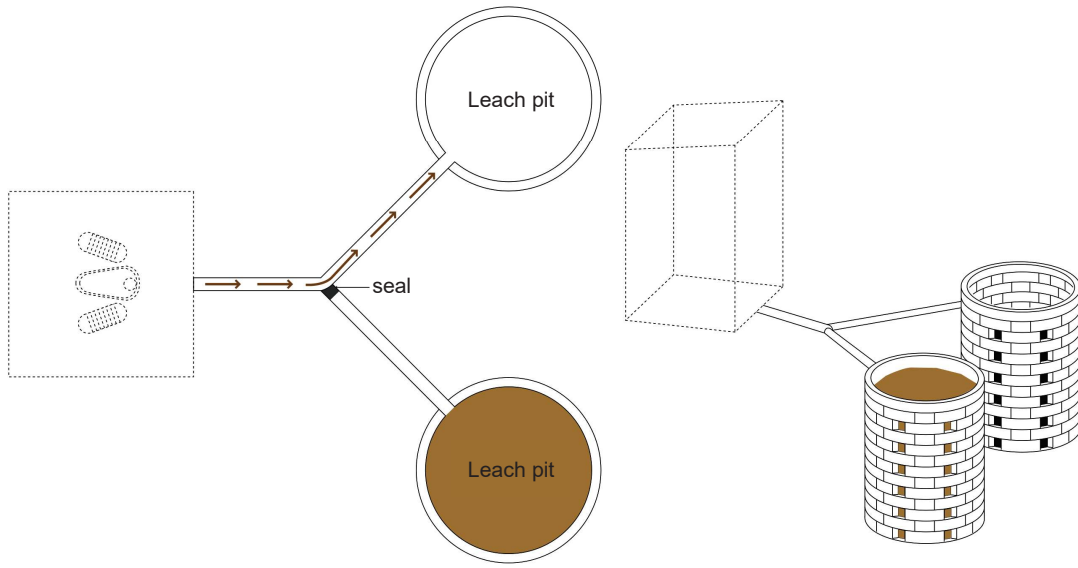


Figure 53: Dry Ecosan toilet

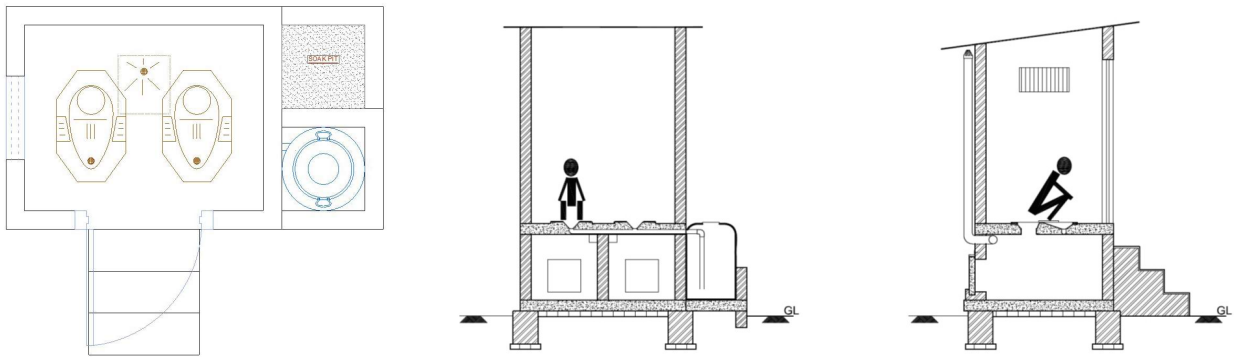
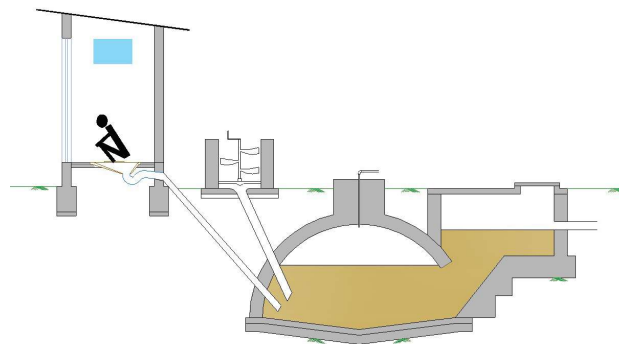


Figure 54: Bio Digester plant



toilet pan or commode. It operates with alternating chambers with one chamber being used at a time. Once a chamber is full, the other chamber is used. The waste in the filled chamber undergoes gradual digestion, transforming into compost that can be easily repurposed for farming. Additionally, the collected urine serves as a liquid fertilizer for agricultural fields.

9.6.3 Biogas Digester

A biogas digester is an airtight container designed to allow the anaerobic digestion of biodegradable waste such as animal manure, domestic waste, black water or sludge and produce biogas and digestate. The biogas is then conveyed using pipe and used to produce energy. Biogas digesters can be installed on different scales like domestic and commercial scales. Domestic-scale biogas digester is mostly used in rural areas while large-scale biogas digester is commonly used in urban context for waste recycling.

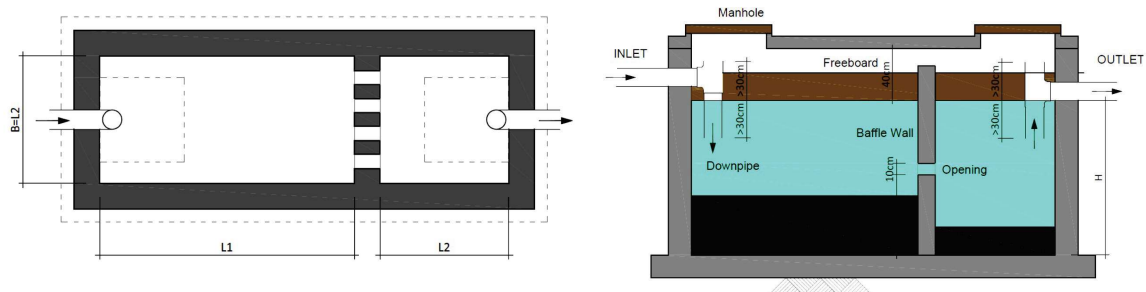
9.6.4 Septic tank

A septic tank (ST) is a primary treatment unit that has major features as follows:

- Watertight: the outer wall must be watertight.
- Two chambers: The chamber at the inlet side should be 2/3 of the following chamber.
- Outlet connected with soak pit or sewer.

Firstly, the process involves settling solids from wastewater, which subsequently undergoes decomposition over time. Once the designed period is over or the system is filled, the sludge is removed and transported to a centralized treatment facility for safe disposal. Generally, the system achieves a removal efficiency of 30 to 50% for Biological Oxygen Demand (BOD) and 40 to 60% for Total Suspended Solids (TSS). The efficiency of the system is primarily influenced by hydraulic retention time and temperature.


Figure 55: Typical septic tank design



Chapter 10

Energy Efficiency

- >> Energy Saving Design Approach
 - >> Heating Ventilating and Air-conditioning (HVAC) System
 - >> On-site Renewable Energy System
 - >> Integrated Design
 - >> Electrical System
 - >> Energy Efficient Technologies, Equipment, and Appliances
 - >> LED Lamp
 - >> Day Lighting system
-



Zero energy house, at Institute of Engineering, Pulchowk
source - <http://mech.pcampus.edu.np/zero-energy-house-ioe-pulchowk/>

10

Energy Efficiency

Energy-efficient building design is a major component of green building design as energy consumption is directly related to the greenhouse gas effect. Therefore, it is obvious that less energy consumed by building is better for controlling global warming as the building sector is liable for consumption of about 40% of global energy. In the Nepalese scenario, the picture is different as electricity generated in our country is from Hydropower, which counts to be much more cleaner energy generation system (24 gCO₂ eq per kWh). This stands third in rank preceded by nuclear power (12 gCO₂ eq per kWh) and Wind power (11 gCO₂ eq per kWh). In contrast, the CO₂ emission from Coal Power Plant is 820 gCO₂eq per kWh and from natural gas power plant is 490 gCO₂eq per kWh.

By conserving energy, we reduce the overall demand on energy resources. We we always must remember that energy we save is energy we produce. Energy efficiency calls for the adoption of efficient practices, designs, methods and technologies that reduce energy consumption ultimately resulting in cost savings. Effectiveness is the capability of producing a desired result or the ability to produce desired output, whereas efficiency refers to ratio of benefits to expenses. Therefore, energy efficiency describes the ratio between the benefit gained and energy used. It is the effective use of energy to support economic growth and social development, while also improving occupants' health and well-being, with little or no adverse effect on the environment (Speer & Miller, 2015).

10.1 Energy Saving Design Approach

Energy-saving design is applicable for both the construction of new buildings and the retrofitting of existing structures. In either scenario, it is meant to achieve a climate-responsive building envelope, and energy efficiency in heating, cooling, lighting and usage of appliances. In addition, it integrates renewable energy sources to meet energy demands.

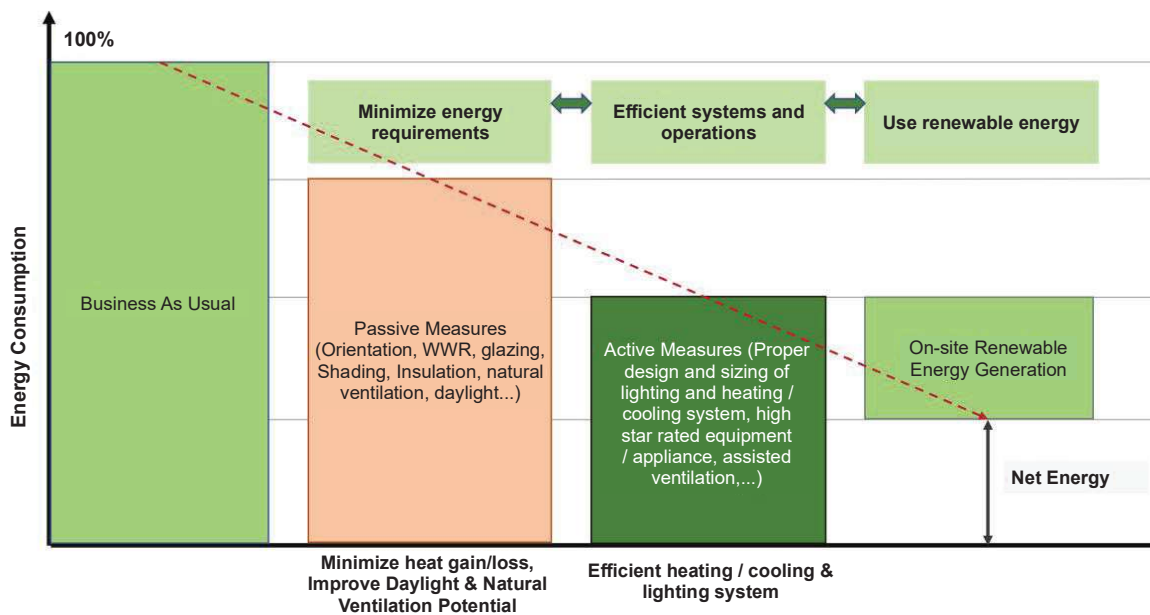
For buildings in Nepal, about 60% energy efficiency can be achieved by adopting a combination of the following strategies:

- Orienting the longer faces toward the south and north.
- Appropriate external shading of windows suitable for the specific orientation
- Insulating the external walls, roof and ground floor
- Installing air-tight double-glazed windows
- Provision of applying cross ventilation when required.

The most effective combination of these strategies will depend on the climate and building usage. (To learn more about it, please refer to Chapters 3 to 6.)

Hence, we must incorporate energy efficiency first principle in design. This means prioritizing an energy-efficient building design and envelope through appropriate site planning, landscaping, proper building form and orientation, and climate-appropriate building envelope design.

Thereafter, apply efficient building services: space heating/cooling and domestic hot water, mechanical ventilation with waste heat recovery, efficient air conditioning if and where needed efficient lighting, and any other electrical services (e.g., for vertical and horizontal transportation) and for any electrical infrastructure equipment (transformers, switchgear, etc.), as well as advanced systems for building management and automation (e.g., building energy and management systems). Applying the energy efficiency-first principle makes it possible to reduce the need for any delivered energy from utilities to a minimum and to minimize the size and capacity of mechanical and electrical building services. The third step, after reducing energy demand and implementing energy-efficient services, is to cover as much of the reduced energy requirement as possible from renewable sources.

Figure 56A: PRINCIPLES OF ENERGY EFFICIENT BUILDING DESIGN

The following actions help reduce energy consumption:

- i. At the beginning of the planning process, a determination should be made to avoid energy-intensive or unnecessary operations.
- ii. The design proposal should consider incorporating measures to minimize energy use by design and operation.
- iii. Application of the best principles of siting and architectural design to reduce energy demands by passive solar design.
- iv. Natural lighting should be used wherever possible.
- v. Installing efficient appliances and taking measures to minimize the need and use of energy-consuming utilities (air-conditioning, water heaters, high-level artificial lighting).
- vi. Lighting design should be based on standards of reduced general lighting with task lighting and highlighting for specific functional considerations rather than lighting all areas equally.
- vii. Feasibility of the use of primary renewable energy sources such as solar, wind, biogas, and geothermal to satisfy the justifiable energy needs.

- viii. Use of energy meters to monitor and illustrate energy consumption to aid in conservation.

10.2 Heating Ventilating and Air-conditioning (HVAC) System

This chapter aims to ensure that HVAC systems are designed, installed, and operated efficiently, while also providing adequate ventilation and maintaining indoor air quality. It addresses various aspects of HVAC systems, including the selection, installation, operation, maintenance of equipment and systems. Moreover, it provides guidelines for ductwork, piping, insulation, and HVAC controls and monitoring systems.

HVAC systems are vital to a building's energy use, accounting for about 30-40% of the total energy consumption in centrally air-conditioned buildings. Thus, designing and installing energy-efficient and sustainable HVAC systems is crucial. The design consultant plays a key role in ensuring compliance with the code and applying all energy-efficient techniques to the HVAC system to minimize energy consumption. By following the guidelines, building owners and occupants can enjoy improved indoor air quality, enhanced thermal comfort, and lower energy bills. Therefore, adhering to the provisions of this section is essential for achieving energy

efficiency and sustainability in building design and construction.

10.2.1 Climatic Conditions

Nepal has a wide range of climate zones and weather patterns, as described in detail in previous chapters. Local climatological data should be obtained from the Department of Hydrology and Metrology or CBE Tool. 2.0% temperature values must be added to define the maximum ambient design temperature for load calculations.

10.2.2 Indoor Design Condition

The size of a heating or cooling system for a building is determined on the basis of the desired indoor conditions that must be maintained based on the outdoor conditions that exist at that location. The desirable ranges of temperatures, humidity, and ventilation rates constitute the typical indoor design conditions. Thermal comfort is a mental state that conveys contentment with the interior surroundings. It is very crucial to consider both physiological (physical) and psychological (mental) aspects when deciding on appropriate thermal comfort levels. The following four environmental parameters are important while designing the HVAC system because these are directly controllable by an HVAC system:

- a) Air temperature (°C),
- b) Radiant temperature (°C),
- c) Air speed (m/s), and
- d) Relative humidity (percent).

In addition to the above four environmental parameters, there are two personal or behavioral parameters that also affect thermal comfort but are not controllable by the HVAC system and they are as follows:

- 1) Activity rate (W/m²), and
- 2) Clothing insulation (m².K/W).

A number of secondary parameters are also important in defining thermal comfort conditions such as radiative temperature asymmetry, temperature gradient, and draught rate. Air conditioning systems for interior spaces shall not be sized more than 26°C for cooling and no lower than 18°C for heating at the occupied level.

10.2.3 Heating/Cooling Load Calculations

The cooling load is determined using the Summer Design Dry Bulb temperature and the Mean Coincident Wet Bulb temperature. These temperatures are used to determine the supply air requirements for the HVAC system. On the other hand, the heating load is calculated based on the winter Dry Bulb temperature. In essence, this means that the HVAC system is designed to deliver the necessary cooling or heating capacity according to the anticipated temperature conditions during the summer and winter seasons.

Design load calculations are the basis of energy efficiency; these shall be done using appropriate software. All energy conservation elements techniques shall be applied to make the project not only energy efficient, sustainable to provide comfort as required. Design consultant will prepare an energy consumption model for both Electrical and thermal.

10.2.4 System Design

HVAC systems are very critical and can be designed in many ways. They are the lungs and arteries of green buildings circulating and refreshing air to ensure a healthy and comfortable indoor climate. Once the heating and cooling load calculation is completed, the design consultant shall compare the energy and cost comparisons for various system types.

HVAC design should be modular where part of the building system can work independently to cope with after-normal working hours needs and part of the building operation can conserve energy. Energy recovery should be considered where feasible and smart thermostats and controls should be utilized for optimized energy usage based on occupancy and outdoor conditions.

A life cycle cost analysis shall be done to show which system is not only energy efficient but also cost-effective during its life cycle. Proper system evaluation should be based not just on initial cost but also on long-term operational efficiency and maintenance.

The following strategies are recommended to reduce active cooling/heating loads.

- Demand Control Ventilation
- Efficient Systems- Pumps, Economizers, Cooling Towers
- Controls-Timeclock, Temperature, Occupancy, Fan and Dampers
- Centralized Demand Shed Controls
- Supply Air Temperature Reset
- Chilled Water Temperature Reset
- Piping and Ducting Insulation
- System Balancing

10.2.5 HVAC System Types

The key to achieving energy-efficient mechanical solutions lies in the selection of highly efficient equipment. High-efficiency equipment is designed to consume less energy over time compared to conventional alternatives while performing the same function. The following guidelines are strongly recommended:

- **Minimize the Building’s Overall Energy Consumption:** Prioritize products and equipment with high-efficiency ratings, verified by industry standards, which support a holistic building design approach.
- **Specify Energy-Efficient Equipment and Technologies:** Select products and equipment with recognized energy-efficiency certifications, ensuring they meet the desired performance standards.
- **Educate Building Owners, Operators, and Occupants:** Provide training on the operation and functionality of installed technologies to maximize energy savings and performance.

In line with Nepal’s sustainability goals, highly efficient mechanical equipment should be installed, featuring:

- High Energy Efficiency Ratio (EER)
- Reputable Manufacturers
- Certified Equipment
- Safe Accessories
- Lower Operating Costs
- Long Equipment Lifespan
- Ozone-Friendly Refrigerant

Most common air-conditioning systems in Nepal can be broadly classified into two types: unitary systems and central air-conditioning systems.

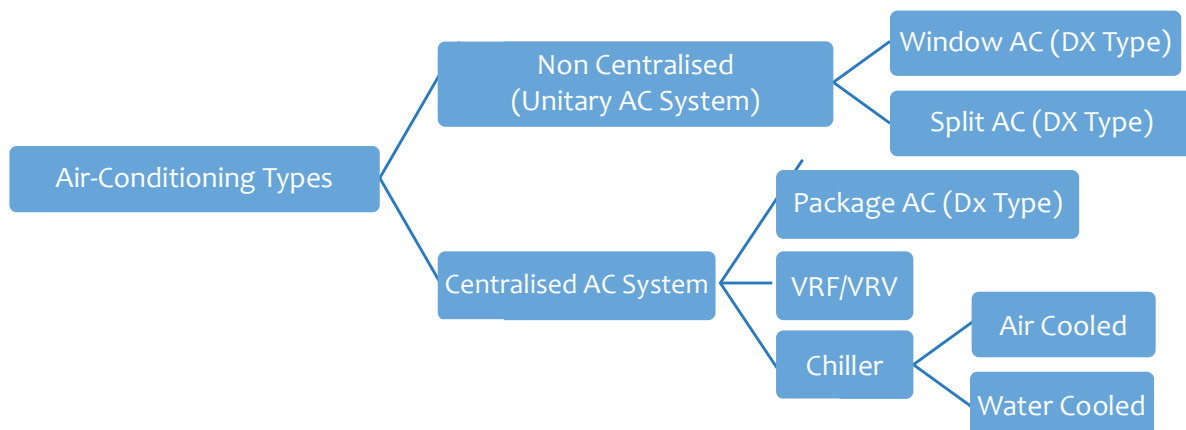
To ensure that buildings are energy-efficient, HVAC equipment, including chillers, unitary air conditioners, split air conditioners, packaged air conditioners, and boilers, must meet or exceed the minimum efficiency standards outlined in ASHRAE 90.1. This standard provides comprehensive guidelines for energy-efficient building design, and adherence to these requirements helps reduce energy consumption and environmental impact. Equipment not specifically listed in the standard’s reference tables try to comply with ASHRAE 90.1 to contribute to the overall energy efficiency of the building.

10.2.6 Low-Energy Comfort System

10.2.6.1 Evaporative cooling

Evaporative cooling is one of the simplest methods of cooling air, and its principle remains a cost-

Figure 56B: Different types of air conditioning systems



effective approach. The process relies on water evaporation to achieve substantial cooling with very low energy consumption and no use of CFCs. This system is applicable only in warm or hot climates and performs better when the relative humidity is low.

In this system, water evaporates directly into the airstream, reducing the air's dry bulb temperature while humidifying it, which can lead to significant energy conservation. In direct evaporative cooling, outside air is blown through a water-saturated medium, typically cellulose honeycomb cooling pads, and cooled by evaporation, with the cooled air circulated by a blower. This process adds moisture to the airstream until it nears saturation, lowering the dry bulb temperature while the wet bulb temperature remains unchanged. By cooling the air through evaporation rather than mechanical refrigeration, this method can significantly reduce the energy required for air conditioning, offering an environmentally friendly and cost-effective alternative.

10.2.7 Radiant heating and cooling

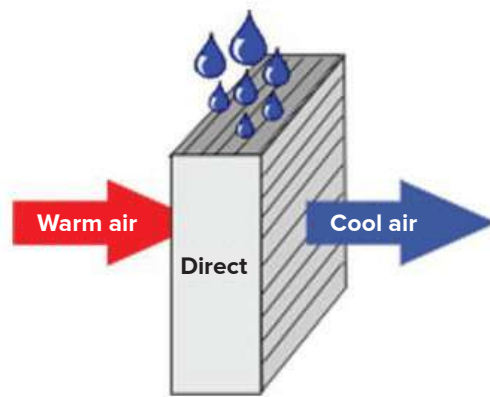
Radiant heating and cooling technologies use convection and radiation to exchange heat with the environment. Unlike conventional HVAC systems that mainly rely on air circulation, radiant systems focus on radiation, complemented by convection and conduction. Radiant heating warms a space through heat emitted from surfaces like floors, walls, or ceilings, rather than heating the air directly.

Radiant cooling uses cooled surfaces to remove sensible heat primarily through radiation, with some convection. Systems such as hydronic radiant cooling circulate cooled water through pipes in panels on floors or ceilings. These systems can be more energy-efficient than traditional all-air cooling systems. They also offer additional benefits in certain applications.

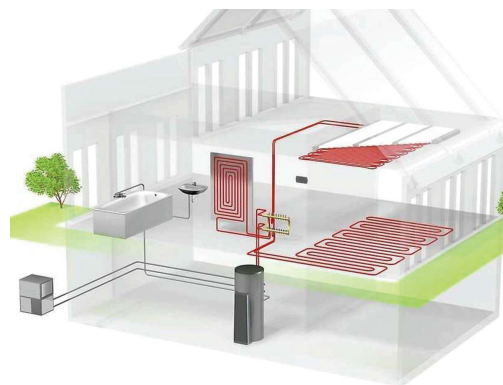
Types of radiant heating & cooling systems

- Air-heated Radiant system
- Electric Radiant heating systems
- Hydronic Radiant heating systems
- Hydronic Radiant cooling systems

Figure 57: Different type of low energy comfort system



(a) Direct Evaporative Cooling System.



(b) Radiant technology Cooling



(c) Portable Evaporative Cooler

Benefits of Radiant Heating and Cooling Systems:

1. **Energy Efficiency:** Radiant cooling systems can save up to 30% in energy compared to conventional systems, with savings ranging from 17% in cooler, humid regions to 42% in hotter, arid areas.
2. **Comfort:** Radiant systems provide more consistent comfort by factoring in radiant temperature, which traditional air systems often overlook. They create a more comfortable environment by aligning with human heat emission patterns.
3. **Cost Savings:** Lower operating and maintenance costs are achieved because radiant systems, especially those with piping embedded in concrete slabs, require minimal upkeep.
4. **Design Flexibility:** Radiant systems allow for more creative architectural designs by reducing the need for bulky equipment and ducts. They can also handle direct solar loads effectively, making them suitable for spaces with high ceilings.

Disadvantages of Radiant Heating and Cooling Systems:

1. **Longer installation time:** It requires relatively longer time and civil works for installation.
2. **Higher initial cost:** The system cost is higher due to the additional civil and labor cost.
3. **Not ideal for retrofitting:** It will require to dismantle existing floor, wall, or ceiling and requires additional civil works and duct routes, which incurs hefty cost and prolonged installation time.
4. **Can cause condensation:** Radiant cooling systems don't remove moisture from the air, so it might need to install a dehumidifier.
5. **Less effective on thick carpeting:** Thick carpeting can insulate the floor, making radiant heating/cooling less effective.
6. **Can be difficult to find skilled professionals:** Because radiant cooling systems aren't widely used, it can be hard to find skilled professionals for installation and maintenance.

10.2.8 Ground Source Heat Pump/Geothermal

A Ground Source Heat Pump (GSHP) is an eco-friendly and renewable heating solution that uses geothermal energy to provide heating and hot water. By extracting natural heat from the ground through geothermal collectors or probes, GSHPs offer efficient, year-round climate control, including cooling during summer.

GSHPs can operate through open or closed-loop systems, with closed-loop systems further categorized into horizontal ground loops and vertical boreholes.

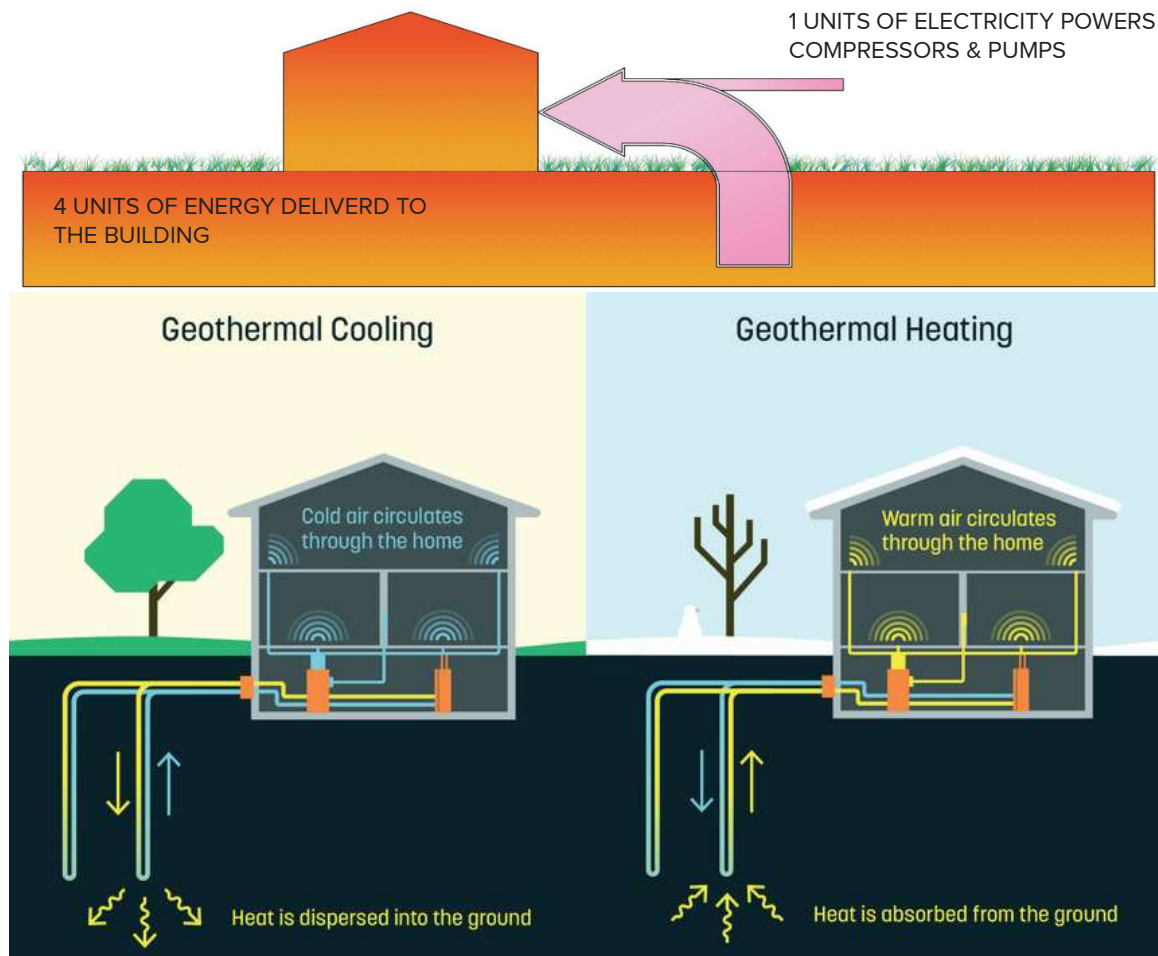
As more homeowners seek sustainable energy solutions, ground-source heat pumps are gaining popularity due to their environmental benefits and cost savings. They can significantly reduce carbon footprints and energy bills, especially when paired with other renewable energy sources like solar panels. Therefore, it is evident that the GSHP system will become more popular in future.

Benefits of Ground Source Heat Pumps:

- **Eco-Friendly:** They utilize natural heat with minimal electricity, making it greener than gas heating. Enhanced environmental benefits can be achieved by combining with solar panels or other renewable energy sources.
- **Energy Efficiency:** GSHPs are highly efficient, with potential efficiencies over 400%, compared to about 95% for gas boilers.
- **Dual Function:** They provide both heating and cooling by reversing its operation.
- **Cost Savings:** Despite higher electricity costs, GSHPs can be cheaper to run annually compared to gas boilers.
- **Performance in Low Temperatures:** They are effective even at temperatures as low as -20°C, suitable for the Nepal climate.
- **Low Maintenance:** They require minimal upkeep, only needing an annual service.

Drawbacks of Ground Source Heat Pumps:

- **Higher initial cost:** Ground source heat pumps are more expensive to install than traditional heating and cooling systems.

Figure 58: Ground Source Heat Pumps Technology

- **Tedious installation process:** The installation process can be disruptive, requiring digging up the premises and installing pipes.
- **Possibility of water contamination:** Open-loop heat pumps can potentially contaminate the water that leads to the building, if necessary, precautions are not taken.
- **Larger space required:** It demands larger sized outdoor space which is not feasible in the all buildings

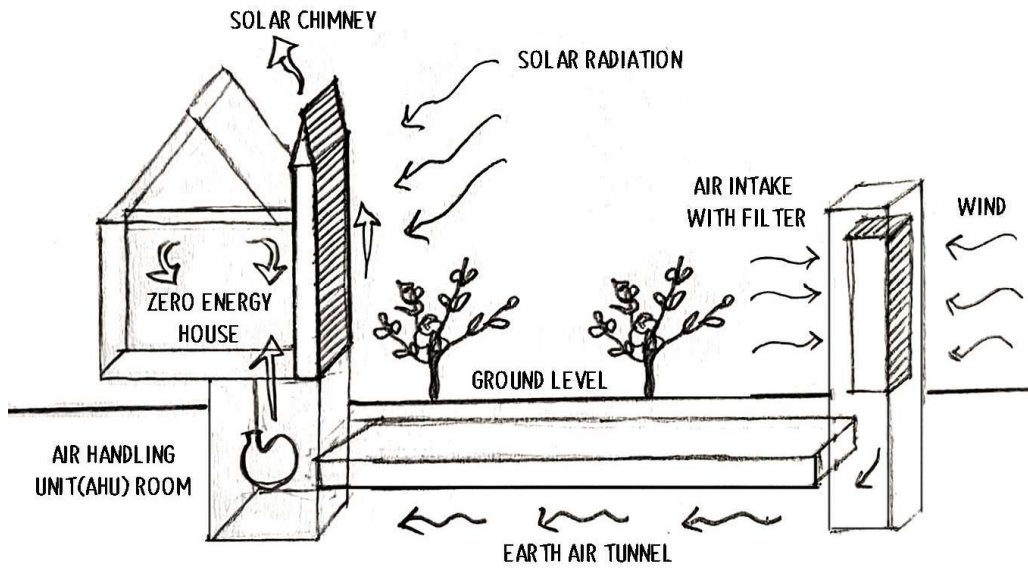
10.2.9 Earth Air Tunnel (EAT)

Earth Air Tunnel is a tunnel designed to pass a calculated amount of air for the purpose of Heating Ventilating and Air Conditioning (HVAC) of a space using natural heat of the earth, four meters below earth surface. It is well-established fact that the temperature of earth below approximately four

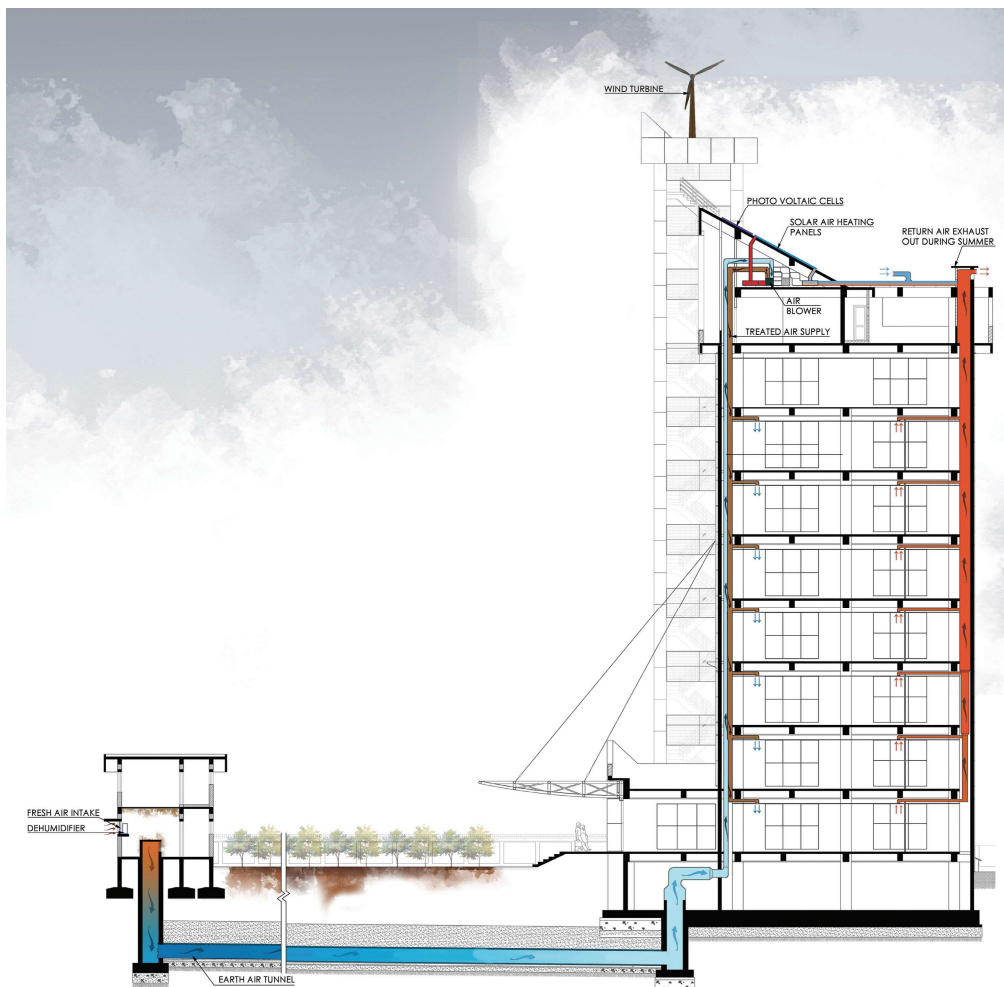
meters remains constant throughout the year unless there is significant water movement underground. Because the ground temperature remains constant, any medium, such as air, when pumped in the appropriate amount and allowed sufficient contact time, will attain the same temperature as the ground temperature. It is to be ensured here that the amount of pumped medium is such that sufficient time is allowed for the heat transfer from the ground to the medium. For all practical purposes we may assume ground to have been infinite heat capacity such that heat transfer to the air does not decrease the temperature of the surrounding earth. When this condition is met, the air attains the same temperature as the earth temperature.

The system consists of 50- to 75-meter-long air tunnel of diameter 0.3 to 0.9 meter at a depth of four meter from the ground surface. One end of the tunnel

Figure 59: Earth Air tunnel system



(a) Schematic diagram of Earth Air Tunnel (EAT) System



(b) Hybrid of EAT and Solar Air Heating system implemented in office building of Butwal Power Company at Kathmandu.

terminates on the fresh air intake above ground with 25 µm filters on four sides of the intake grills while the other side terminates in the Air Handling Room. The Air Handling Unit can be a conventional type of AHU, used in comfort air conditioning applications, but without cooling and heating coil. Because of the need to dehumidify the air coming out of the tunnel, the tunnel outlet is not connected directly to the AHU. The air is first directed into the AHU room where it is dehumidified with the help of portable dehumidifiers. It is then distributed to the rooms through a system of standard GI ducts and diffusers. It is advised to place a dehumidifier at tunnel intake where atmospheric conditions have high humidity in order to minimize condensation inside the EAT, as high moisture contain inside EAT may cause mold and bacteria growth, which is injurious to health of the occupants.

The air after picking up the heat load from the room or after releasing the heat into the room, depending on whether the system is used for cooling or heating, is allowed to pass to solar chimney through return air grills and GI ducts. The solar chimney can be designed as an integral part of the building architecture. It should face south and absorbs solar energy. The solar chimney warms the return air and increases the buoyancy of the air to facilitate its exhaust through the roof outlet. In order to further assist the movement of the air, wind driven ventilator can be installed at the top of the solar chimney. Conventional exhaust blowers can be used to drive the stale air out of the room after it completes its heat transfer.

10.2.10 Hybrid of Earth Air Tunnel (EAT) and Solar Air Heating (SAH) System.

In Warm Temperate Climate zone and above, where winter temperature drops around 0°C and where humidity is high, merely EAT system cannot achieve comfortable indoor condition. In order to achieve a comfortable indoor environment during winter in these areas, it is advised to use Hybrid of EAT and SAH System. In this system the treated air from the EAT (around 15°C in Kathmandu) is used as preheated air supply to SAH System, which in turn boost the supply air temperature up to 32°C.

10.2.11 Air Source Heat Pump

An air source heat pump (ASHP) system is similar to ground source heat pump (GSHP) system. Major difference is an ASHP uses outdoor air as a heat source instead of heat underneath ground like in GSHP. An ASHP system also uses a refrigeration system to move heat from the outside air into a building. ASHP also can be used for heating and cooling. A ground source heat pump is typically more efficient than an air source heat pump, however, a ground source heat pump is more expensive to buy and install at the outset. In contrast, air source heat pumps are easier and more affordable to install, especially where space is limited, making them a popular choice. There are two types of ASHP system:

- **Air-to-water:** It moves heat from the outside air into the central water heating system.
- **Air-to-air:** It moves heat from the outside air into the building using fans.

Advantages of Air Source Heat Pumps:

- ASHPs are energy efficient and can be combined with other energy efficient technologies.
- Low initial cost.
- Easy to install.
- They don't require a naked flame or combustible gases.

Drawbacks of Air Source Heat Pumps:

- ASHPs may lose some of their heating capabilities in very cold weather.
- ASHP requires periodic maintenance.
- Some properties may not have the right space to install an ASHP.

Air source heat pump system is similar to VRF of VRV type AC system. However, an air source heat pump is typically a smaller, single-zone system, while a VRF system is designed for large buildings with multiple zones, allowing for precise temperature control in different areas through its ability to adjust refrigerant flow individually to each zone, making it significantly more complex and potentially more energy efficient in large buildings with diverse cooling and heating needs.

10.2.12 Mechanical Ventilation

Mechanical ventilation should be avoided, whenever possible, by opting for passive ventilation strategies. However, there are instances where it becomes necessary. In such cases, every mechanical ventilation system, whether for supply or exhaust, should include an easily accessible switch or alternative method to shut off or reduce ventilation when full operation is not needed. The system must also be equipped with automatic or gravity dampers that close when not in use, for both outdoor air intake and exhaust. Additionally, any dampers used to shut off ventilation should be designed to provide a tight seal to minimize air leakage. Furthermore, to optimize energy efficiency in these spaces, the following factors should be considered:

- Spaces should be located as near as possible to an external wall in order to minimize the distance air has to be extracted.
- Ducting design and fan specification should be carried out to minimize energy consumption.
- Controls such as movement sensors, CO2 monitors and timers should be used to ensure that spaces are not over-ventilated when not in use.

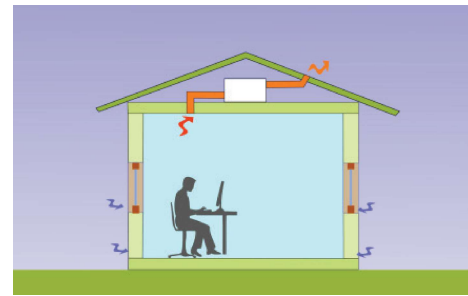
The Ventilation rates provided to each occupied space should meet the requirements specified in the ASHRAE 62.1 Standard, based on the type of space, to ensure acceptable indoor air quality. For office spaces, the simplified table below can be used as general guidance as per ASHRAE 62.1 standard. The total fresh air volume is calculated as follows:

$$\text{Total fresh air volume} = (\text{per person rate} \times \text{number of occupants}) + (\text{area rate} \times \text{area})$$

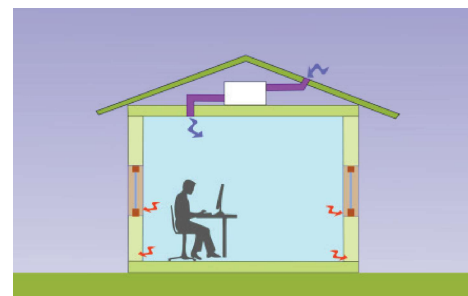
Fresh air rates for a typical office building (Source: ASHRAE 62.1)

Per person rate m3/h(cfm)	Area rate m3/h/m2(cfm/m2)
30.0	1.0

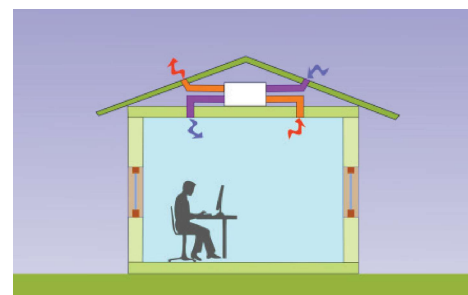
Figure 60: Types of Mechanical Ventilation



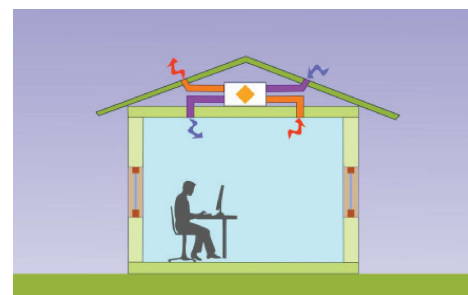
(a) Extract ventilation system



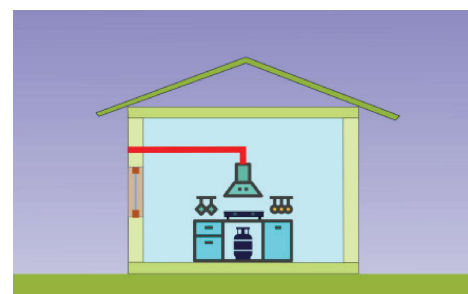
(b) Supply ventilation system



(c) Balanced ventilation system



(d) Balanced heat recovery ventilation system



(e) Spot ventilation

The following types of mechanical ventilation system can be used to maintain indoor air quality

10.2.12.1 Extract ventilation systems

Extract ventilation systems operate by depressurizing the building. The system mechanically removes indoor air, lowering the internal air pressure below the external pressure. This pressure difference allows fresh air from outside to enter the building through leaks and intentional passive openings.

10.2.12.2 Supply ventilation systems

Supply ventilation systems operate by pressurizing the building. Fresh outside air is forced into the building, causing stale indoor air to exit through the building's shell, openings, bathroom and kitchen ventilation ducts, and other intentional outlets.

10.2.12.3 Balanced Ventilation Systems

Balanced ventilation systems, when properly designed and installed, maintain equal pressure between indoor and outdoor environments, preventing pressurization or depressurization of the building. These systems work by bringing fresh outdoor air inside while exhausting polluted indoor air outside.

Typically, a balanced ventilation system consists of two fans and two duct systems that ensure effective distribution of fresh air by strategically placing supply and exhaust vents. Although vents can be installed in every room, traditional balanced systems are designed to supply fresh air to areas where people spend most of their time, like

bedrooms and living rooms, while exhausting air from spaces where humidity and contaminants are commonly generated, such as kitchens, bathrooms, and laundry rooms.

10.2.12.4 Balanced heat recovery ventilation system

The basic design of a balanced ventilation system is enhanced by incorporating heat-recovery units. These units help reduce heating and cooling costs by transferring heat between the exhaust air and fresh supply air as needed. They also improve comfort by moderating the temperature of the incoming air and minimizing drafts before the air is delivered.

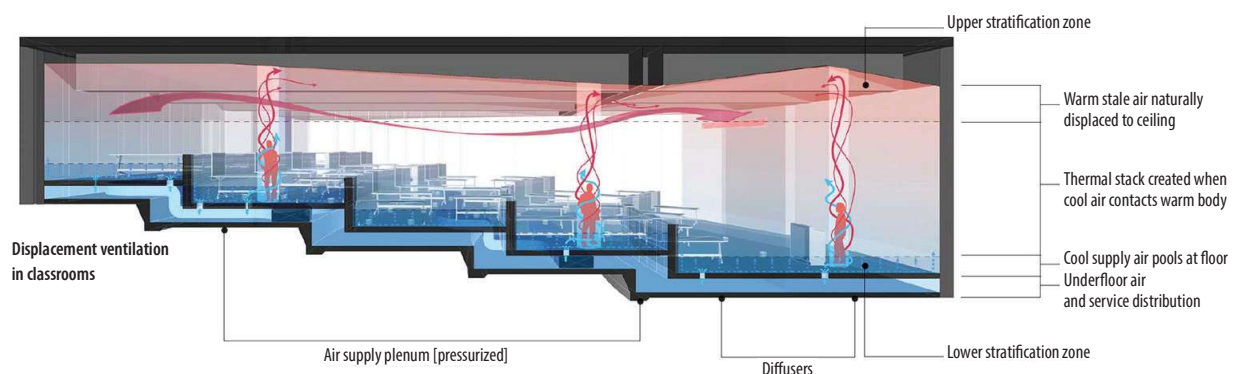
10.2.12.5 Spot ventilation

Using localized exhaust fans, such as those in kitchens and bathrooms, is crucial for enhancing air quality, whether you're relying on natural or whole-house ventilation strategies. Spot ventilation improves the efficiency of ventilation systems by removing contaminants at their source as soon as they are produced. It should be an essential component of any building's ventilation design.

10.2.12.6 Displacement ventilation

Displacement ventilation is a type of HVAC system that delivers cool air near the floor level, creating a natural convection current that improves air quality, reduces noise, enhances thermal comfort, and saves energy. This system is particularly effective in high-ceiling spaces as it targets the occupied area and prevents heat or cool air loss to unoccupied zones.

Figure 61: Displacement Ventilation



10.2.13 Controls

10.2.13.1 System Control

All mechanical cooling and heating systems can be controlled by automated systems, preferably integrated into a building management system using Direct Digital Control (DDC). The DDC system must:

1. Maintain the required indoor temperature and humidity levels.
2. Manage the system's operation according to various schedules for different days, usage types, and times of the week.
3. Retain programming and time settings for at least 10 hours during a power outage.
4. Include an accessible manual override for temporary system operation.

Additionally, the system should:

- a) Report maintenance needs of the components through a Maintenance Management System.
- b) Monitor, alarm, and report on energy consumption.
- c) Communicate with the facility's fire systems.

10.2.13.2 HVAC Systems Zone Set Points (Temperature Control)

Zone set points are critical for effective temperature control within a building. These set points define the desired temperature for different zones or areas, ensuring that each space maintains an optimal and comfortable environment. The adjustability of zone set points allows for customization based on various factors such as occupancy patterns, time of day, and specific comfort needs. Modern HVAC systems often incorporate advanced control mechanisms that utilize sensors to monitor and dynamically adjust these set points as well as ensure precise temperature management. This not only enhances occupant comfort but also contributes to energy efficiency by reducing unnecessary heating or cooling. By tailoring temperature control to individual zones, HVAC systems improve both comfort and operational efficiency thereby impacting overall building performance and energy consumption.

10.2.13.3 Variable-Speed Equipment

HVAC systems with variable-speed control should be programmed to automatically reduce the maximum

speed of the equipment to 90% of its design speed during automated demand response (DR) events. Additionally, any adjustments to airflow must ensure that the supply airflow rate remains above the level necessary to meet minimum outdoor airflow requirements and avoid causing negative effects on building pressurization.

10.2.13.4 Fault Detection and Diagnostics (FDD)

A fault detection and diagnostics (FDD) system is recommended for installation in new buildings to oversee the HVAC system's performance and detect faults. The FDD system should: include permanently installed devices to monitor HVAC operations; sample system performance no more than once per hour; automatically identify, display, and report faults; notify service personnel of identified issues; provide prioritized repair recommendations based on data analysis; track and record the history of faults from identification through repair completion; and report any increases in energy usage.

10.2.13.5 Smart Building Integration and Automation:

Smart building systems integrate various technologies, such as HVAC, lighting, security, and energy management, into a unified, automated system. This integration allows for real-time data analysis and decision-making, enabling precise control of building operations. By automatically adjusting settings like temperature, lighting, and ventilation based on occupancy patterns and environmental conditions, smart building systems reduce energy waste and optimize overall efficiency which leads to substantial energy savings.

10.2.13.6 Occupancy Sensors and Demand-Controlled Ventilation:

Occupancy sensors detect the presence of people in different areas of a building and adjust lighting and HVAC systems accordingly. When spaces are unoccupied, lights can be dimmed or turned off, and HVAC systems can reduce ventilation and heating/cooling, saving energy. Demand-controlled ventilation (DCV) further optimizes energy use by adjusting ventilation rates based on occupancy levels or indoor air quality. Integrating these technologies reduces energy consumption as it ensures that energy is only used whenever and wherever it is needed.

10.2.13.7 Energy Monitoring and Management Systems:

These systems provide real-time data on a building's energy consumption, allowing facility managers to identify inefficiencies and track energy usage patterns. By monitoring energy use across various systems and devices, these systems enable targeted interventions to reduce consumption, such as adjusting operational schedules, fine-tuning equipment settings, or identifying areas for retrofit or upgrade. Integrating energy monitoring with smart building automation and occupancy sensors creates a cohesive approach to energy management, further reducing overall energy consumption and promoting continuous improvement in energy efficiency.

10.2.14 Piping and Ductwork

Design, layout and insulation of HVAC piping and ductwork is crucial for minimizing heat loss or gain, reducing operating costs, and improving overall system performance. Here are some effective strategies:

10.2.14.1 Insulation:

- Proper Insulation: Use high-quality insulation materials with appropriate R-values based on the system's operating temperature and local climate.
- The 'Glass Wool' should not be used, as it is injurious to health (eye and lungs). Instead 'Rock Wool and 'Mineral Wool' can be used. Following insulation materials can be used depending upon requirement of R-value, density, moisture resistance, fire resistance, and pricing: XLPE (Cross-linked Polyethylene), Fiberglass blanket insulation, Foam glass, Expanded Polystyrene (EPS) foam insulation, Extruded Polystyrene (XPS) foam, Spray foam, Calcium Silicate, Fiberboard, Polyurethane foam insulation, Phenolic foam, Ethylene Propylene Diene Monomer (EPDM) rubber insulation, Hemp-wool, and Hempcrete.
- Continuous Coverage: Ensure the insulation covers the entire length of the piping and ductwork, with no gaps or breaks.
- Weather Protection: Protect insulation exposed to outdoor elements with weather-resistant coverings to maintain its effectiveness.

10.2.14.2 Design and Layout:

- Minimal Length: Keep piping and ductwork runs as short as possible to reduce heat transfer and pressure losses.
- Avoid Obstacles: Minimize the number of bends, elbows, and other obstructions that can increase friction and energy consumption.
- Proper Sizing: Ensure piping and ductwork is sized appropriately to match the system's capacity and avoid excessive pressure drops.

10.2.14.3 Materials:

- Low-Friction Materials: Use materials with low friction coefficients, such as smooth-walled pipes and ductwork, to reduce pressure losses and energy consumption.
- Corrosion-Resistant Materials: Choose materials that are resistant to corrosion because corrosion can reduce pipe and ductwork efficiency and lead to leaks.

10.2.15 System Balancing

System balancing is a crucial process that ensures optimal performance, energy efficiency, and comfort in HVAC systems. By adjusting airflow or water distribution rates, balancing optimizes the system's operation, leading to lower energy consumption, improved thermal comfort, longer equipment lifespan, and reduced operating costs. All HVAC systems shall be balanced in accordance with established engineering standards.

10.2.15.1 Air System Balancing

Air System Balancing involves adjusting airflow rates within HVAC systems to ensure each space receives the intended amount of air. This is achieved by manipulating dampers, splitter vanes, extractors, or automatic controls like constant or variable air volume boxes.

Balancing is essential to verify system performance and optimize efficiency. Proper balancing devices should be installed at every supply air outlet and zone terminal to allow for adjustments. These devices, typically shown on the mechanical plans, must be verified during installation.

Design options for improving air distribution efficiency include:

- Variable-air-volume systems
- VAV diffusers
- Low-pressure-drop duct design
- Low-face-velocity air handlers
- Fan sizing and variable-frequency-drive motors
- Displacement ventilation systems

10.2.15.2 Hydronic System Balancing

Hydronic System Balancing involves adjusting water flow rates within heating and cooling systems to ensure even distribution to all devices. This is achieved by manually adjusting valves or using automatic flow control devices.

A balanced hydronic system delivers equal water flow to all components, resulting in optimal efficiency and reduced energy consumption. It minimizes pressure drops, allowing for consistent performance without needing to adjust supply temperatures for individual zones.

Hydronic systems must be balanced to prioritize minimizing throttling losses. Then, the pump impeller should be trimmed or its speed adjusted to achieve the desired flow rates.

10.2.16 Economizers

Economizers are energy-saving devices that utilize cooler outdoor air to reduce the building's cooling load. They consist of dampers, sensors, actuators, and logic controls that work together to determine the optimal amount of outside air to bring in.

When the outside temperature is lower than the inside, the economizer shuts down the compressor and introduces outside air through the economizer louvers. This can result in significant energy savings, often up to 10% of a building's total energy consumption. The effectiveness of an economizer depends largely on the local climate and the building's internal cooling needs.

10.2.16.1 Air Economizer

An air economizer is a system that harnesses the natural cooling power of outdoor air to reduce or eliminate the need for mechanical refrigeration in

HVAC systems. It typically consists of a ductwork arrangement, dampers, and an automatic control system. By strategically introducing cooler outdoor air into the building, an air economizer can significantly lower energy consumption during mild or cold weather conditions.

10.2.16.2 Water Economizer:

A water economizer is a system that indirectly cools the supply air of an HVAC system using water as an intermediary. The water itself is cooled through heat or mass transfer to the environment, bypassing the need for mechanical refrigeration. This approach can be particularly effective in regions where there's a reliable source of naturally cool water, such as groundwater or nearby bodies of water.

10.3 On-site Renewable Energy System

On-site renewable energy systems are energy systems that use renewable energy sources like solar, wind, or geothermal power to generate energy on the same property where it is used. They can be used for a variety of applications including electricity, heating, and cooling.

10.3.1 Solar Energy System

Solar energy is most abundant, popular, and widely used in different dispositions:

- Solar Room Heating/Cooling System
- Solar Water Heating System
- Solar Electricity Generation System

10.3.1.1 Solar Room Heating/cooling System

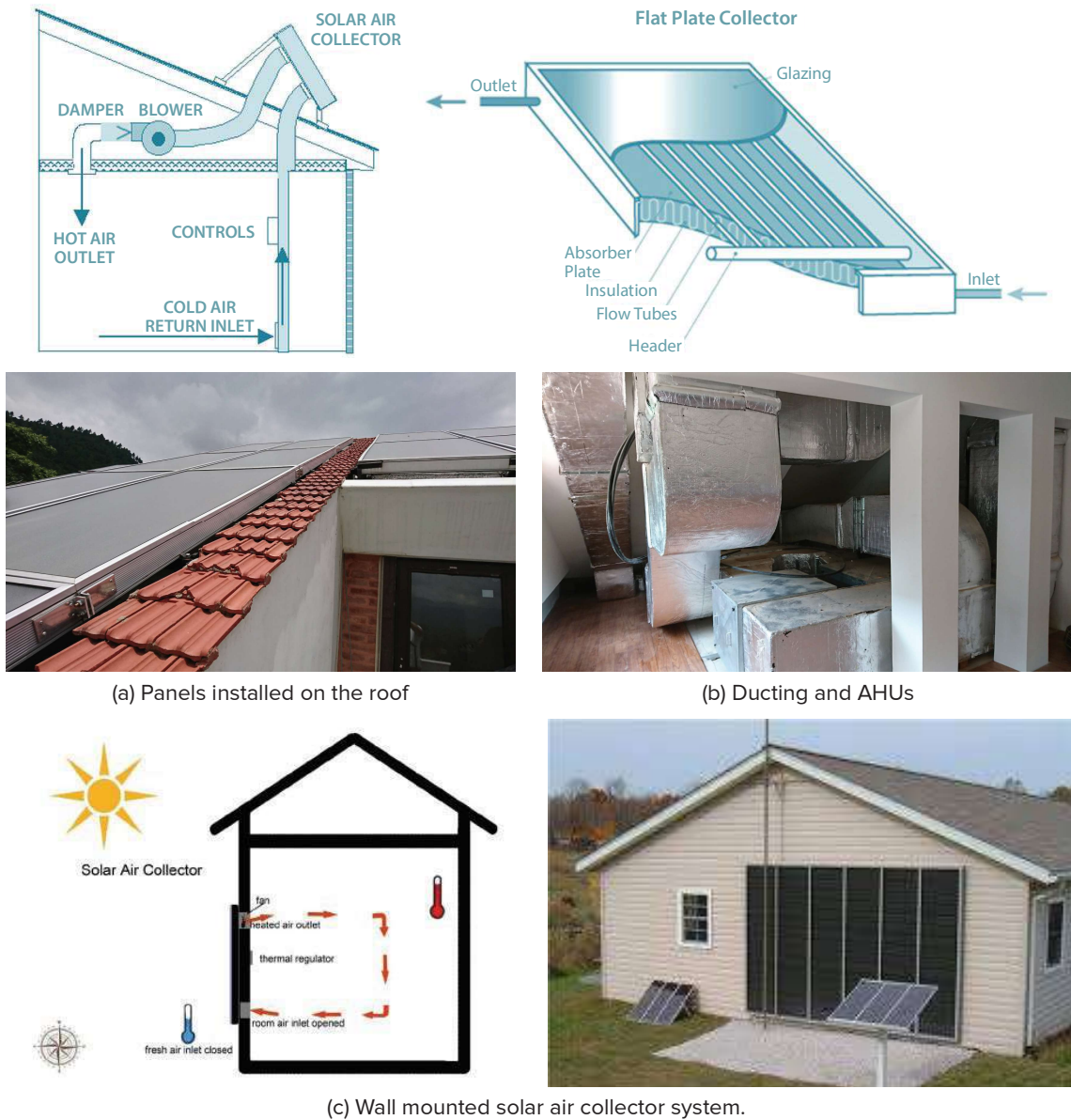
There are two types of solar room heating systems:

- Active System
- Passive System

A. Active Solar Heating System

Active solar heating system comprises of solar air heating panels and mechanical ventilation system. Panels are usually installed on roof orienting south with 40° inclination. It is also mounted on wall to function similar to the Trombe Wall System.

Figure 62: Solar air heating panel



(a) Panels installed on the roof

(b) Ducting and AHUs

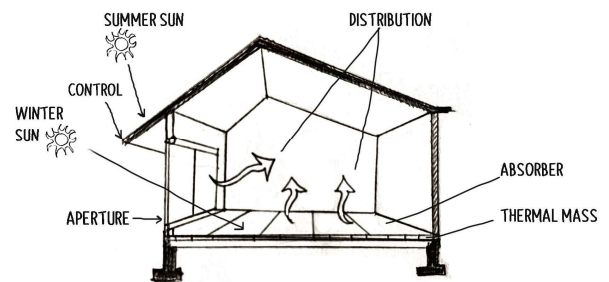
(c) Wall mounted solar air collector system.

B. Passive Solar Heating System

A passive solar design has five elements (Williams, n.d.) which are as follows:

- a. **Aperture/Collector:** Aperture is the glass area through which sunlight enters the building. The aperture(s) should face within 30 degrees of true south and should not be shaded by other buildings or trees from 9a.m. to 3p.m. daily during the heating season.
- b. **Absorber:** The hard, darkened surface of the storage element. The surface, which could be

Figure 63: Five elements of passive building design



a masonry wall, floor, or water container, sits in the direct path of sunlight. Sunlight hitting the surface is absorbed as heat.

- c. **Thermal mass:** Materials that retain or store the heat produced by sunlight. While the absorber is an exposed surface, the thermal mass is the material below and behind this surface.
- d. **Distribution:** Method by which solar heat circulates from the collection and storage points to different areas of the house. A strictly passive design will use the three natural heat transfer modes- conduction, convection and radiation.
- e. **Control:** Roof overhangs can be used to shade the aperture area during the summer months. Other elements that control overheating include electronic sensing devices, such as a differential thermostat that signals a fan to turn on; operable vents and dampers that allow or restrict heat flow; low-emissivity blinds; and awnings.

B.1. Types of passive solar heating techniques

B.1.1. Direct gain system

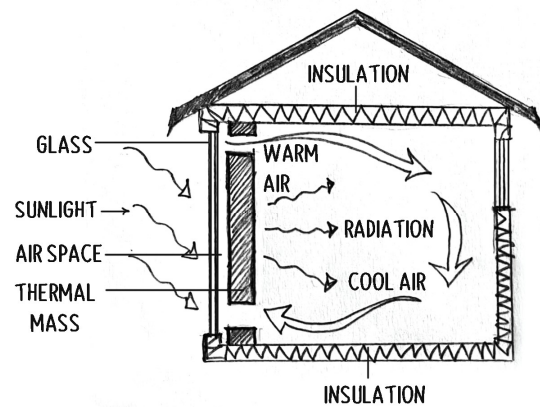
The actual living space functions as a solar collector, heat absorber and distribution system. South facing glass admits solar energy into the house where it strikes masonry floors and walls, which absorb and store the solar heat, which is radiated back out into the room at night as shown in figure. These thermal mass materials are typically dark in color in order to absorb as much heat as possible. The direct gain system utilizes 60-75% of the sun's energy striking the windows. For a direct gain system to work efficiently, thermal mass must be insulated from the outside temperature to prevent collected solar heat from dissipating. Heat loss is especially likely when the thermal mass is in direct contact with the ground or with outside air that is at a lower temperature than the desired temperature of the mass.

B.1.2. Indirect gain system

In an indirect gain of solar passive heating system, thermal mass is located between the sun and the living space. The thermal mass absorbs the sunlight that strikes it and transfers it to the living space by conduction. The indirect gain system utilizes 30–45% of the sun's energy striking the glass adjoining the thermal mass. The examples of indirect gain system are as follows.

B.1.2.1. Trombe wall

Figure 64: Trombe wall system



In indirect gain solar passive heating system, Trombe wall absorbs and stores heat during the day. Excess heat is carried out by passage air between wall and glass through thermosyphon principle into the indoor space as shown in Figure. At night Trombe wall vents are closed and the storage wall radiates heat into the indoor space.

The first design strategy to increase the effectiveness of Trombe Walls is painting the outside surface of the wall to black (or a dark color) for the best possible absorption of sunlight. A typical Trombe wall consists of a 4 to 16in (10 to 41cm)-thick, south-facing masonry wall with a dark, heat-absorbing material on the exterior surface and faced with a single or double layer of glass. The thickness of the thermal mass depends on the type of material used. Trombe walls are usually made of solid materials, such as concrete, brick, stone, or adobe.

The glass is placed from $\frac{3}{4}$ to 2 inches (2 to 5 cm) from the masonry wall to create a small airspace (Torcellini & Pless, 2004). However, the minimum 4-inch gap between the glass and the mass allows cleaning the glazing and the insertion of a roll-down radiant barrier as needed.

Natural daylight is lost in the full-height Trombe walls unless the system is combined with a direct-gain system or windows are introduced. Properly sized roof overhangs shade the Trombe wall during the summer. Shading the Trombe wall can prevent the wall from getting hot during the time of the year when the heat is not needed.

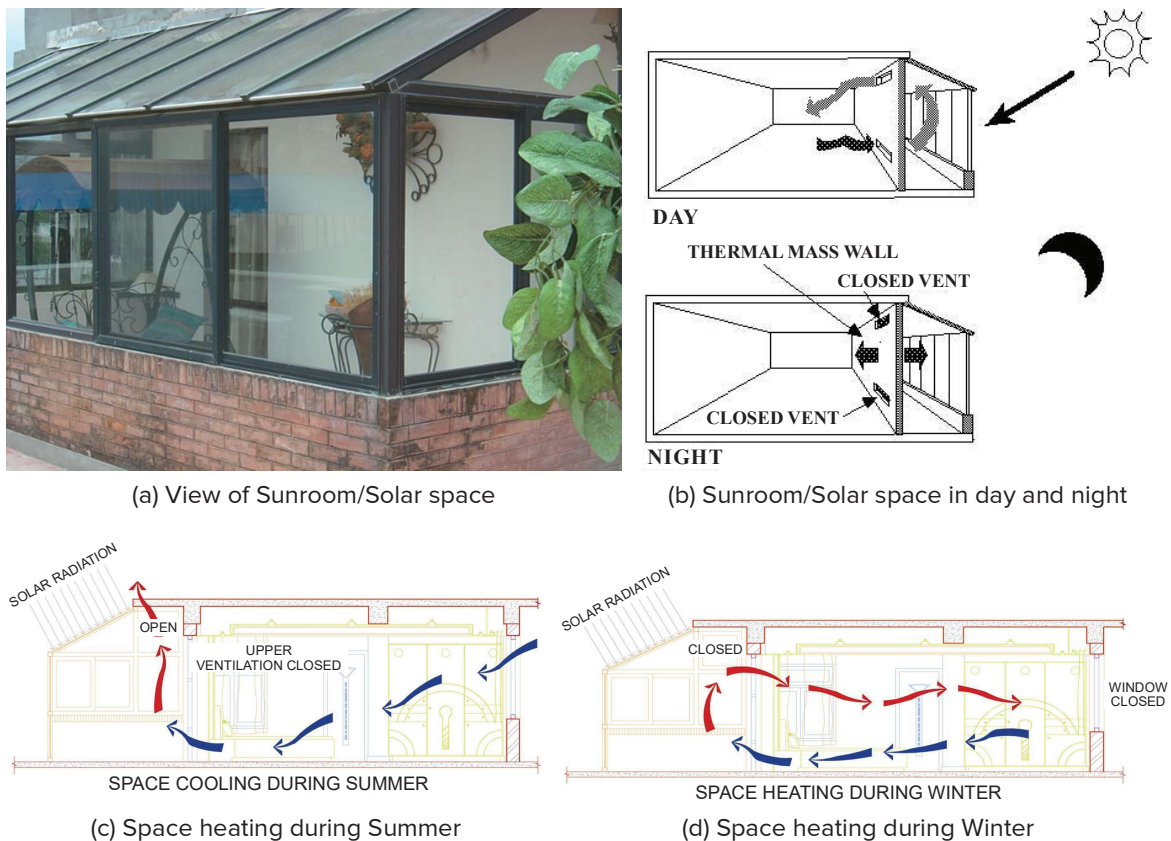
B.1.3. Isolated gain

An isolated passive solar heat gain system has its integral parts separated from the main living area of a house. Isolated gain involves utilizing solar energy to passively move heat from or to the living space using a fluid, such as water or air by natural convection or forced convection. A few examples of isolated gain are as follows:

B.1.3.1 Sunroom

It integrates a combination of direct gain and indirect gain system features. Sunlight entering the sunroom is retained in the thermal mass and air of the room. Sunlight is brought into the house by means of conduction through a shared mass wall in the rear of the sunroom or by vents that permit the air between the sunroom and living space to be exchanged by convection.

Figure 65: Solar space



C. Passive cooling system

Passive solar cooling systems work by reducing unwanted heat gain during the day, exchanging warm interior air for cooler exterior air when possible, and storing the coolness of the night to moderate warm daytime temperatures. Passive cooling systems are the least expensive means of cooling a home which maximizes the efficiency of the building envelope without any use of mechanical devices. It relies on natural heat sinks to remove heat from the building. They drive cooling directly from evaporation, convection, and radiation without using any intermediate electrical devices. The passive cooling systems are as follows:

C.1. Landscaping

Landscape plays a crucial role in maintaining the microclimate of the site. Landscaping involves the deliberate change of the contours of the earth, and the planting of trees and other vegetation. It plays a major role in protecting the building from cold winter winds and from the hot summer sun. Plants can be used effectively around a building to reduce energy consumption. For the details, please refer to Chapter 4.

C.2. Solar shading

Solar shading is an effective approach to passive cooling techniques. Shading can reduce summer

temperatures by blocking up to 90 percent of direct sunlight and therefore helps improve comfort and save energy (Ecosis, 2010). For the details refer to section 6.3.

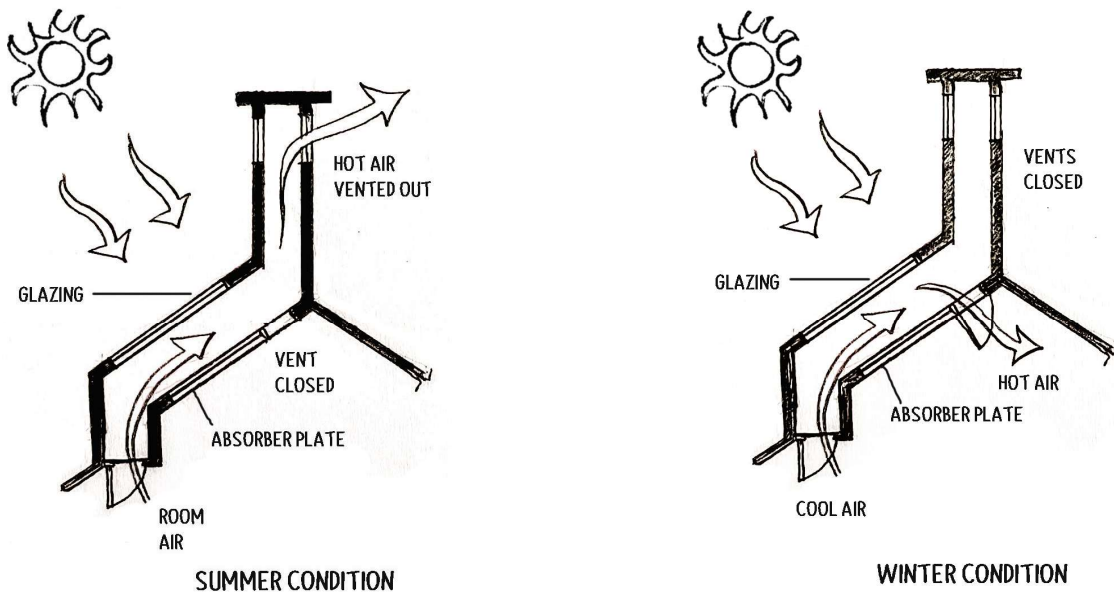
C.3. Induced ventilation techniques

C.3.1. Solar chimney

Solar chimneys are particularly effective for creating a draft in hot, humid climates that have very few

options for cooling. The chimney unit consists of external glazing, absorber plate, insulation board, vents. The incident solar radiation is absorbed by black painted surface on the chimney. Heated air rises up and passes through internal vent to room during winter. After heating the room, cool air passes to chimney and repeat the process. The solar chimney system is very easy to maintain, its installation cost is very low and operation cost is almost zero.

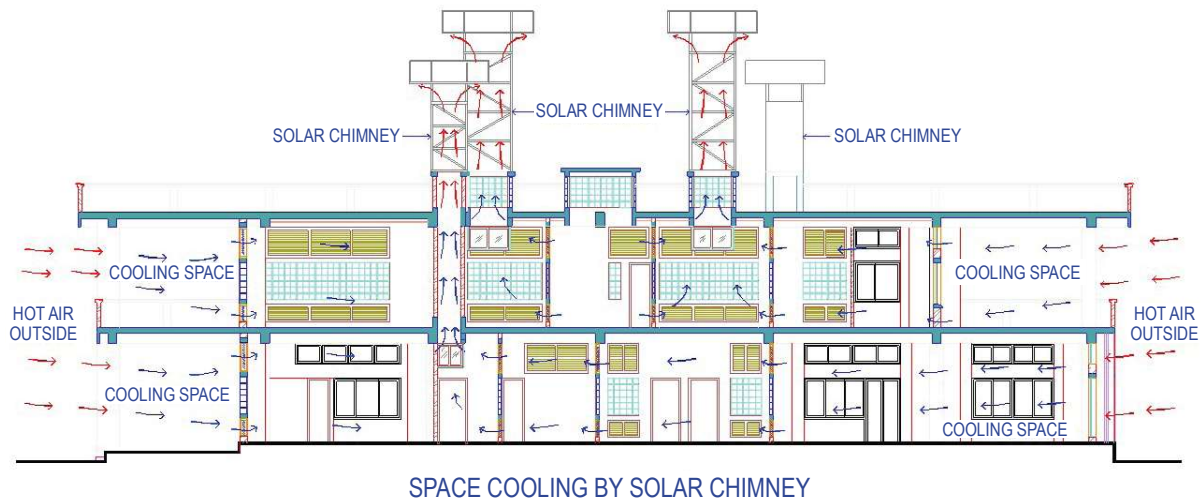
Figure 66: Solar Chimney



(a) Solar Chimney in summer and winter conditions



(b) South Facade of the Regional Educational Directorate Building at Hetauda.

Figure 67: Section drawing Regional Educational Directorate Building

In this system, once the air inside the solar chimneys (painted in matt black color) is heated by solar rays, the hot air will flow upwards. This action in turn will develop a draught system for creating pleasant breezing in rooms below. It is preferable to provide deep shaded verandahs as cooling zone at the west and east end of the building. At first stage, hot air outside will start cooling down once it enters shaded cooling zone and at second stage the air continues to cooling down with breezing effect inside rooms as it flows through louvers at partition wall to next room. The height of the Solar Chimney has to be worked out such that it will create natural air draft system in the rooms at night. From midnight until early morning, the air temperature will drop significantly. Due to the chimney effect (caused by the height difference) cool air flow will flow through and cool down walls, floor, ceiling and furniture in the office room. As a result, the thermal mass effect will keep the office room cool until the early afternoon hours. During winter, the solar chimney can be closed with a trap door.

10.3.2 Solar Water Heating System

Solar water heating systems are divided into two types:

1. Active Solar Water Heating System
2. Passive Solar Water Heating System

10.3.2.1 Active Solar Water Heating System

An active solar water heater system uses the sun's energy to heat water by using collectors, pumps,

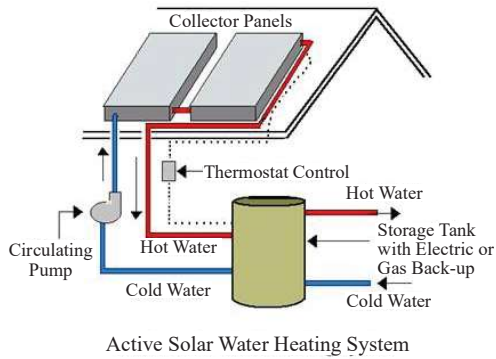
and valves to move water from the collectors to a storage tank. This system is much more flexible in terms of placement of cold-water tank, hot water tank, and solar collector itself. Thus, it provides an Architect to achieve more aesthetically pleasant exterior design of a building. It is possible to hide both the tanks inside the building and place solar collectors amalgamating with slope roof of the building. The functions of various components of the active solar heating system are as follows:

- i. **Collectors:** Capture solar radiation
- ii. **Pump:** Activates the circulation of the water or working fluid
- iii. **Storage system:** Stores the hot water
- iv. **Back-up system:** Provides additional electrical heating elements when the solar system can't provide enough
- v. **Controls:** Regulates the system's operation
- vi. **Sensor:** Give the level of real-time solar radiation available to the controller

Factors that affect solar heat production

- i. **Collector design**
- ii. **Surface area of collector**
- iii. **Type of working fluid or water**
- iv. **Local climate and site conditions**
- v. **Insulation** - The storage tank and piping connections should be well insulated to prevent heat loss.

Figure 68: Solar Water Heating System



(a) Active solar water heating system diagram.

(b) Controllers

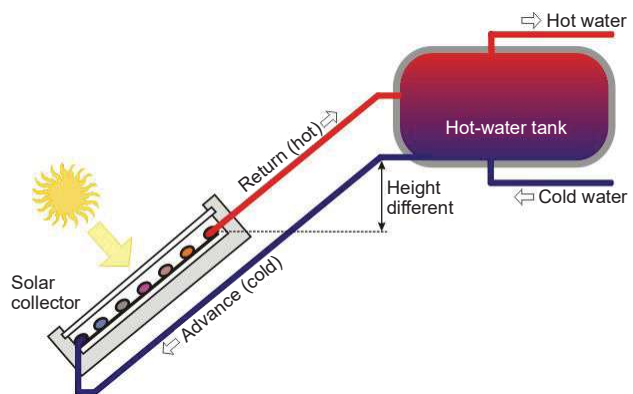


(c) Active solar water heating system installed on slope roof.



(d) Hot and cold-water tanks

Figure 69: Passive Solar Water Heating System



10.3.2.2 Passive Solar Water Heating System

Passive Solar Water Heating System is similar to the active one, except it does not comprise pump and control devices. The system works on gravitational flow from the cold-water tank, which should be

positioned at least 7'-0" above the bottom level of the solar collector. Height difference between the hot water tank and top level of the solar collector should be minimum as the circulation here is based upon thermodynamics of water (hot water flows up and cold water flows down).

10.3.3 Wind Energy System

Wind energy system also is divided into two types:

1. Active Wind Energy System
2. Passive Wind Energy System

10.3.3.1 Active Wind Energy System

Wind energy used for the generation of electricity by wind turbines is referred to as the Active Wind Energy System. The use of wind energy is gaining popularity worldwide as it is the cleanest form of energy production (11.0 gCO₂ eq per kWh). There are several potential sites for the development of wind energy in Nepal. Places above the Churiya range in Nepal experience 15-17 hours of wind every day. Mustang, Dhading, Galchhi and Bhorlini are some of those places that provide favourable conditions for electricity generation.

There are two basic types of wind turbines:

1. Horizontal-axis turbines

A horizontal-axis wind turbine (HAWT) turns wind energy into electricity using the aerodynamic force from the rotor blades, which work like an airplane wing or helicopter rotor blade. When wind flows across the blade, the air pressure on one side of

the blade decreases. The difference in air pressure across the two sides of the blade creates both lift and drag. The force of the lift is stronger than the drag and this causes the rotor to spin. The rotor connects to the generator, either directly (if it's a direct drive turbine) or through a shaft and a series of gears (a gearbox) that speed up the rotation and allow for a physically smaller generator. This translation of aerodynamic force to the rotation of a generator creates electricity. Small-sized horizontal-axis turbines are used in building projects. However, large-sized horizontal-axis turbines are more popular for large-scale projects and wind farms.

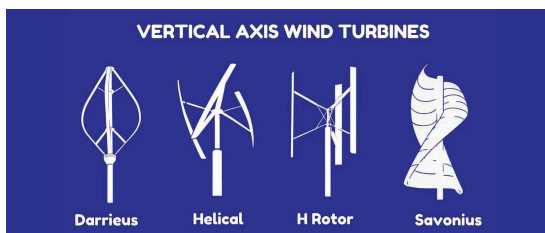
2. Vertical-axis turbines.

A vertical-axis wind turbine (VAWT) is a type of wind turbine where the main rotor shaft is set transverse to the wind while the main components are located at the base of the turbine. This arrangement allows the generator and gearbox to be located close to the ground, facilitating service and repair. VAWTs are not as scalable as HAWTs, which makes them less suitable for large-scale wind farms. They are better suited for smaller installations, such as for residential or commercial use. VAWT are less prone to accidents during high velocity wind/storm.

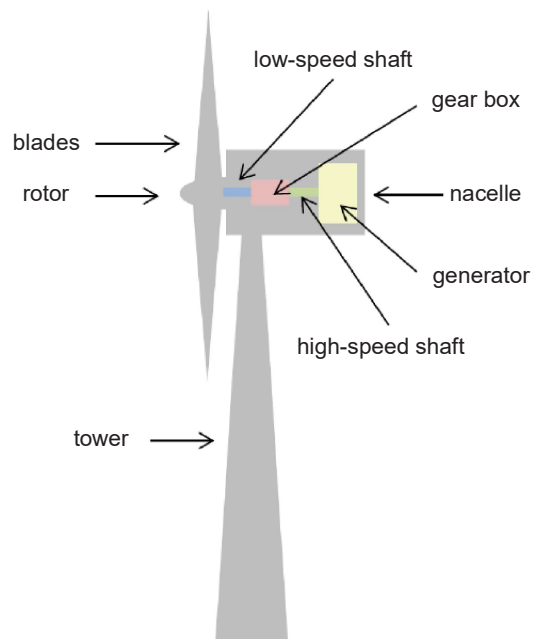
Figure 70: Solar Water Heating System



(a) Horizontal Axis wind turbine



(c) Various type of vertical axis wind turbines



(b) Side elevation of Horizontal Axis wind

10.3.3.2 Passive Wind Energy System

Passive wind energy systems are divided into the following types:

A. Wind driven roof ventilator

Wind driven roof ventilators are getting popular in our country day by day due to their simplicity in installation and operation. The turbine ventilator operates by utilizing the velocity energy of the wind to induce air flow by centrifugal action. The centrifugal force caused by the spinning vanes creates a region of low-pressure area which draws air out through the turbine. Air drawn out by the turbine is continuously replaced by fresh air from the outside.

The slightest breeze will cause the turbine to spin and even after the breeze has stopped, the fly wheel effect of the rotor cage will use its stored energy to continuously remove air giving rise to ventilation. Suction is maintained even at low wind velocities. Hot air becomes lighter and accumulates at the center apex of the shed.

Due to the ease of installation and the versatility of the system, turbine ventilators have multiple applications in the home, the office, and on an industrial scale. They're a low cost and environment-friendly alternative to air conditioning and, as they extract damp, condensed air, they support the integrity of the building's structural materials, such as the roofing tiles, ceiling boards and wooden roof beams. They are also clean, green commercial suction machines that remove fumes, dust, smoke and chemicals to create healthy, more productive work environments in the manufacturing, engineering, chemical, pharmaceutical and hospitality industries. Turbine roof ventilators are fresh, completely natural ventilation solutions with an array of benefits, some of which are:

- i. Quick and easy installation
- ii. Economical
- iii. Quiet, clean and eco-friendly

- iv. Maintenance free
- v. Operate 24/7
- vi. Do not require electricity
- vii. Available in a variety of sizes, materials and models

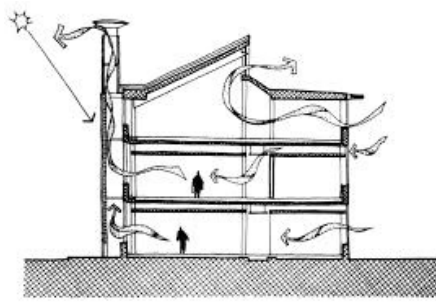
B. Cross ventilation and stack ventilation

Cross ventilation involves creating air inlets on opposite sides of the building to allow fresh air to flow through. It is effective in areas with regular wind patterns, and you should choose cross ventilation if your building is oriented to take advantage of prevailing winds. This strategy is particularly useful in moderate to windy climates.

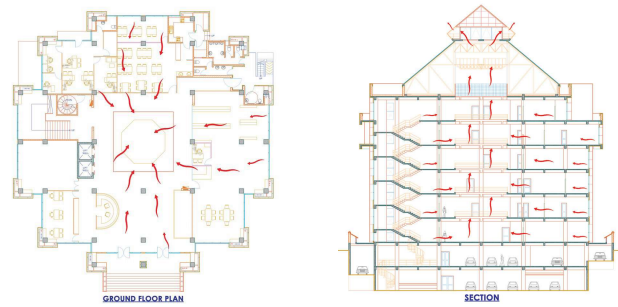
Passive stack ventilation relies on the principle of warm air rising and cool air entering lower openings. It effectively utilizes the stack effect to promote natural airflow, and you should choose this strategy if your building has vertical shafts or well-designed interior pathways that can channel warm air upwards. Passive stack ventilation works well in various climates, including both cold and hot regions.

Figure 71: Turbine roof Ventilator



Figure 72: Cross ventilation and stack ventilation

(a) Hot air rises due to buoyancy, and its low pressure sucks in fresh air from outside



(b) Office Building of Department of Electricity Development at Sano Gaucharan, Kathmandu. Pyramid shaped solar space is designed to enhance stack effect. Hot air developed at solar space will create better draught effects.

10.3.4 Biogas

Microorganisms who thrive in the absence of air digests the organic material and releases a mixture of gases. The gases thus produced contain mostly methane along with other gases like Carbon dioxide, Nitrogen and Hydrogen Sulphide in small quantities. This process is known as anaerobic digestion. Methane is a colorless and odorless gas and is highly flammable. Methane is not poisonous. There are many types of Biogas Production System developed all over the world. In contrast to firewood, cooking with Biogas also does not produce any harmful smoke. The digestate from the systems can be used as biological fertilizer which improves agricultural yields. In Nepal, following two types of Biogas Plant are in use:

10.3.4.1 Domestic Biogas Digesters

The Biogas Digester or Biogas Plant is a device which helps us in collecting this gas and use it as fuel. The operation of biogas systems reduces the demand for non-sustainably used firewood and at the same time reduces CO₂ emissions as a result of deforestation and combustion of the wood. The installed dome-shaped systems are developed in Nepal and provide enough energy for a family with at least two cows or buffaloes. The cattle manure is mixed with water and added to the system. Anaerobic decomposition of the organic matter promotes the formation of biogas, which is fed into the kitchen via pipe connections and used for cooking.

10.3.4.2 Food Waste Biogas Plant

Biogas generation using food waste anaerobic co-digestion with activated sludge provides a cleaner addressable system, an excellent solution to global challenges, the increasing energy demands, fuel charges, pollution and wastewater treatment. Anaerobic digestion is an emerging technology that is already competing for the place of the most efficacious multipurpose technology of the century. It addresses the two most challenging problems of waste disposal and clean renewable energy generation synergistically. The biogas which is produced from the anaerobic digestion contains about 65–75% methane (CH₄) and about 35–45% carbon dioxide (CO₂). This can be converted for fuel application as compressed natural gas (CNG). Anaerobic digestion is a direct interspecies electron transfer (DIET) system, where synergistic microbial consortia work and thrive together. There are four distinct phases during anaerobic digestion: 1) Hydrolysis, 2) Acidogenesis, 3) Acetogenesis and 4) Methanogenesis carried out by a consortium of various microorganisms.

At recent years, Plastic Stacked Barrel Biogas Plant getting popular in Nepal, as it is simple and easy to operate. It can be installed on rooftop or at corner of garden.

Basics of the Plastic Stacked Barrel Biogas Plant is as follows:

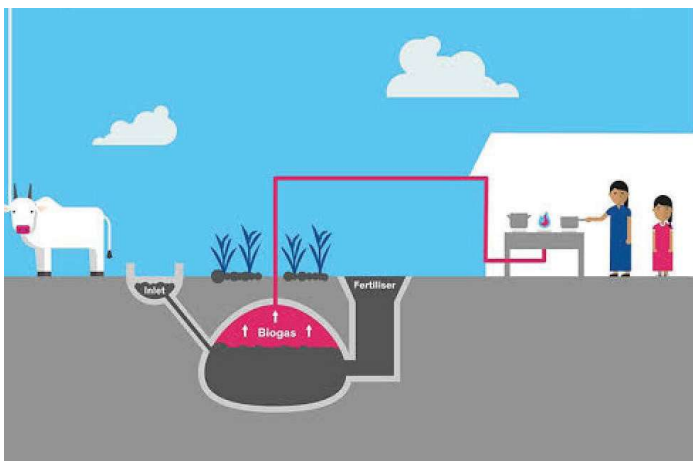
- The Biogas plant consists of a digester tank, where the organic material is stored, and the microorganisms work on them and release gas.

- The gas produced is collected in a tank known as gas collector. In a floating type model, this tank is floating in the slurry and moves up and down based on the amount of gas stored in it.
- A guide pipe helps the gas collector tank to move up-and-down inside the digester tank.
- Waste is fed through feed pipe inside the digester tank.
- The fully digested slurry drains out through the outlet pipe. This can be collected, diluted and used as fertilizer for plants.
- A gas pipeline from the Gas collector tank helps in utilizing the gas for cooking and lighting
- A simple thumb rule for biogas plant for home use is 5 kilograms of waste (daily) needs a 1,000.00-liter capacity digester. A 500-liter gas holder tank filled with gas can be used for about an hour in one burner.

10.4 Integrated Design

The current design process typically follows a linear sequence of four stages: architectural design, structural design, building services design (encompassing water and sanitary systems, electrical systems, and HVAC systems for buildings with air conditioning), and finally construction (Figure 74 A). However, architects, due to their specialized

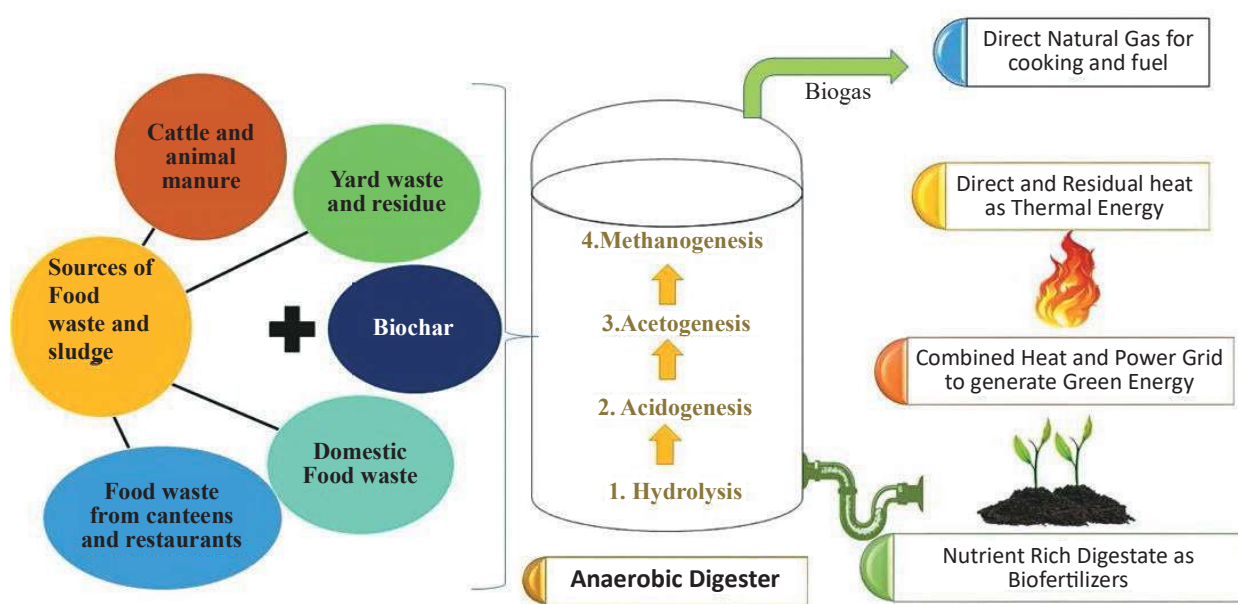
Figure 73: Bio gas plant



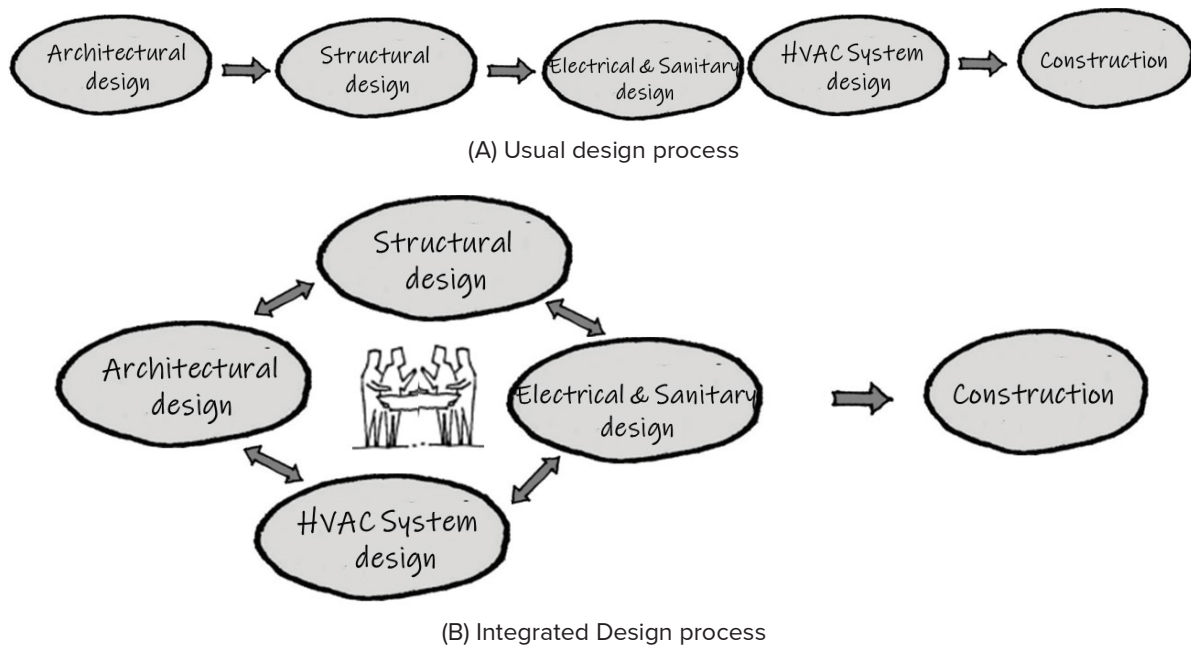
(a) Typical biogas plant diagram



(b) Plastic stacked barrel biogas plant.



(c) Schematic diagram of Plastic stacked barrel biogas plant.

Figure 74: Design processes

training, often have limited knowledge of complex structural design and building physics. As a result, architectural decisions frequently compromise the building's safety, resource efficiency, energy performance, and occupant comfort. Consequently, each design step is often carried out independently, which can lead to incompatibilities between different design elements. These disconnects can result in significant challenges during construction and negatively impact the overall performance and functionality of the building

To overcome these challenges, there is a growing need to shift the design methodology and adopt an integrated design model (Figure 74 B). The integrated design approach brings together architects, engineers, energy experts, and other stakeholders early in the design process. This collaboration ensures that decisions made throughout the design phase are in line with the building's sustainability goals

10.5 Electrical System

Electrical system of Green Building Design consists of utility power supply, backup supply, renewable energy, control panels, distribution feeders, internal wiring, and control switches, etc. During the design safety and reliability shall be considered and local and international standard must be followed. The

electrical system of a green building is designed to be energy-efficient and reduce the building's environmental impact.

10.5.1 Energy efficient consumption behavior

Understanding and changing household energy consumption behavior are considered as effective ways to improve energy efficiency and promote energy conservation. With the increasing penetration of conventional and emerging information and communication technologies in the energy sector, traditional energy systems are also being digitized in our country. This data provides a new way to analyze and understand individuals' energy consumption behavior and improve energy efficiency and promote energy conservation. Energy-efficient consumption behavior is a way of living that reduces unnecessary energy use and promotes sustainable energy practices. Here are some examples of energy efficient behaviors:

- i. **Curtailment:** Turning off appliances when not in use, such as lights, fans, and AC, etc.
- ii. **Maintenance:** Keeping appliances and equipment in good working order.
- iii. **Buying energy-efficient products:** Purchasing products that use less energy and have a lower environmental impact

- iv. **Lifestyle changes:** Setting thermostats higher in the summer and lower in the winter
- v. **Transportation:** Walking, cycling, or taking public transportation instead of driving
- vi. **Using appliances during off-peak hours:** Reducing energy costs and strain on the grid by using appliances during less busy times.

10.5.2 Lighting power density

Lighting power density (LPD) measure the amount of energy a building or space uses for lighting per unit of area. It's typically measured in watts per square foot or square meter. LPD is used by energy codes to determine compliance by comparing the designed energy per square foot to the amount allowed by code. LPD includes the power used by: Light fixtures, Ballasts, Controls, and Transformers. LPD is often associated with the lighting power allowance (LPA) permitted by the building's energy code. To reduce lighting loads, more efficient light sources and fixtures need to be considered. These can also reduce cooling loads for the same amount of visible brightness.

10.5.3 Electric power distribution

Electrical power distribution in a green building is a significant component in ensuring the building's sustainability, energy efficiency, and environmental performance. Here are some key considerations for electrical power distribution in green buildings:

- a) **Lights, appliances and controls** - Use of High-Efficiency Lighting, Lighting Controls, and Energy-Efficient Appliances and Equipment result into reducing energy consumption. Hence, it contributes towards minimizing load in an electric power distribution system.
- b) **Renewable Energy Integration:** Renewable energy integration in Green Building is getting common practice these days. Its large-scale successful implementation in several European countries shows very much promising positive result on minimizing load on Electric Power Distribution system. Solar photovoltaic (PV) panels and Wind turbines are commonly integrated into the design of green buildings to generate electricity as renewable sources, whereas geothermal system is getting popular recently. A building's electrical distribution

system must be equipped with inverters, grid connection systems, and battery management systems to handle the variable and decentralized nature of renewable energy. These systems can be grid-tied, off-grid, or hybrid systems, depending on the building's energy needs and local regulations.

- c) **Smart Grid and Smart Building Technologies** - Smart grids and smart buildings are technologies that work together to improve the efficiency, reliability, and security of the power grid. Smart Grid use digital technologies, sensors, and software to balance electricity supply and demand in real time, whereas Smart Building use smart devices to improve energy efficiency and reduce energy bills. These devices can include:
 - **Smart Meters and Energy Monitoring:** Green buildings often incorporate smart meters to monitor energy consumption in real time, helping building owners and managers identify inefficiencies, track energy use, and make informed decisions about energy-saving measures.
 - **Demand Response Systems:** Smart power distribution systems can adjust energy consumption based on grid demand or pricing signals, optimizing energy use and reducing costs.
 - **Building Management Systems (BMS):** A centralized BMS can control lighting, HVAC, and other systems for energy optimization, ensuring that the building operates at peak efficiency while maintaining occupant comfort.
- d) **Distributed Generation and Microgrids** - Distributed generation is a small-scale energy source like solar power, wind power, batteries, biogas, and biomass that can power a single structure, whereas Microgrid is a localized electric grid that can operate independently from the main grid. Microgrids can be found at major industrial facilities, military bases, and large college campuses. Peltric electricity generation system, which is very popular in remote area of our country is also considered to be a Microgrid system.
- e) **Grid Connectivity:** A green building's power distribution system must be designed for efficient grid connectivity, allowing for the import

and export of power between the building and the utility grid.

- f) **Energy Storage and Backup System** - Energy storage systems (such as Flooded lead-acid batteries, Lithium-ion batteries or Advanced flow batteries) are integral to green buildings for storing excess power generated from renewable sources and for providing backup power during grid outages. Critical systems, such as computers, IT, elevators or emergency lighting, critical health care systems, may require UPS systems to ensure continuous operation during power interruptions.
- g) **Voltage and Power Quality Management** - Green buildings need to consider voltage regulation to ensure stable operation of all electrical equipment, reducing the risk of equipment damage or malfunction. Portable voltage stabilizer can be considered to each sensible equipment like computer, IT system, Audio-video system, and refrigerator. If the project site area has a very poor voltage supply, then the central voltage stabilizer should be installed. A building's electrical system should aim to maintain a high-power factor to ensure that energy is used efficiently and reduce losses in the distribution system. It can be achieved by Power Factor Correction (PFC). The details of PFC are dealt in Chapter 10.6.5.
- h) **Sustainable Electrical Materials** - Electrical distribution materials like cables, switches, and transformers can be selected based on their environmental impact. Green buildings should prioritize materials made from recycled or sustainably sourced materials. Use of low-EMF (electromagnetic fields) and low-toxic wiring, such as halogen-free cables, is increasingly common in green buildings to promote healthier indoor environments.
- i) **Electric Vehicle (EV) Charging Infrastructure** - Many green buildings include electric vehicle charging stations to support the use of electric cars, reducing carbon emissions associated with transportation. The electrical power distribution system must accommodate the additional load from multiple EV chargers, with considerations for capacity, safety, and user accessibility.
- j) **Resilience and Redundancy** - Green buildings should be designed with electrical power

resilience in mind, ensuring that the electrical system can handle disruptions from external events (e.g., natural disasters or grid failures) without compromising occupant safety and building operation. Critical systems (e.g., life-safety systems, HVAC, and data centers) should have built-in redundancy, such as backup generators or dual power feeds, to ensure reliable operation.

- k) **Code Compliance and Standards** - Electrical systems should also comply with local electrical codes and safety regulations which may have specific requirements for renewable energy integration, energy storage systems, and grid interconnection. However, designer can opt to standards requirements for energy performance, sustainable materials, and system integration set by international standards of green buildings such as LEED, BREEAM, or the Living Building Challenge.

10.5.4 Voltage-drop

The design should ensure minimal voltage drop reducing energy waste, improving the lifespan of electrical equipment, and maintaining the intended operation of systems. Followings are the consideration which should be taken in account to reduce voltage drop:

- a) **Energy Efficiency:** Voltage drop represents a loss of electrical energy as current flows through conductors, such as wires and cables. A higher voltage drop means more energy is lost as heat, which is inefficient. For green buildings, minimizing voltage drop helps reduce overall energy consumption, contributing to lower operational costs and a smaller carbon footprint.
- Properly designed electrical systems ensure that devices and appliances receive the correct voltage. Voltage drop can reduce the effectiveness of energy-efficient devices, lighting systems (e.g., LEDs), HVAC systems and Elevators making it harder to meet sustainability goals.
- b) **Electrical System Design:** To minimize voltage-drop, electrical conductors must be properly sized. Larger conductors have less resistance and, therefore, experience less voltage drop. Green building designs often incorporate longer cable runs due to the expansive nature of

modern, energy-efficient layouts. This requires careful calculation of conductor size to meet voltage drop standards.

Voltage drop should be accounted for when planning distribution panels and circuits. An effective design will balance the length of wire runs with appropriate wire sizes, ensuring that voltage drop stays within acceptable limits (typically no more than 3% for the entire system and no more than 2% for feeder circuits).

c) **Renewable Energy Systems:** Renewable energy systems, such as solar panels or wind turbines require efficient power conversion and distribution. Excessive voltage drop can reduce the effectiveness of these systems, causing a loss of generated energy before it reaches the building's electrical load

d) **Smart Grid Integration:** Many green buildings are designed to integrate with smart grid systems for energy management. These systems rely on stable voltage levels to optimize performance. A high voltage drop can lead to voltage instability, which negatively impacts smart grid functionality and the overall energy management system.

e) **Voltage Drop Calculations:** The voltage drop is influenced by several factors:

- **Conductor Material:** Copper and aluminum are commonly used for conductors, with copper being more efficient due to its lower resistance.

- **Wire Length:** Longer wire runs result in higher voltage drop.

- **Current Load:** The higher the current, the greater the voltage drop.

Common formulas used to calculate voltage drop: $V_{drop} = 2 \times L \times I \times R / 1000$

where:

V_{drop} = voltage drop in volts

L = one-way length of the conductor in meter

I = current in amperes

R = resistance of the conductor per 1000 m (depending on material)

f) **LEED and Other Green Building Standards** – International green building standards have emphasized voltage drop by including it in energy credits and life cycle assessments.

g) **Building Automation and Control Systems:** Green buildings often incorporate automation systems that manage lighting, HVAC, and other critical functions to optimize energy use. Voltage drop can interfere with the proper operation of these systems, causing them to malfunction or become less responsive. Similarly, Smart lighting systems depend on stable voltage levels to function efficiently. A voltage drop in the circuit could lead to dimming or erratic behavior which reduces the effectiveness of these energy-saving technologies.

h) **Consideration for Electric Vehicles (EVs)** - With the rise of electric vehicles, green buildings often include EV charging stations. These stations can cause significant voltage drops if not designed properly, especially if charging multiple vehicles simultaneously. Ensuring that the wiring and electrical panels are capable of handling the increased load without excessive voltage drop is important to maintain the efficiency of both the charging stations and the building's electrical system.

i) **Voltage Monitoring:** Incorporating voltage monitoring systems into the building's electrical network allows for the early detection of voltage drop issues. If voltage levels start to fall outside of specified ranges, it can signal a potential problem in the system, such as overloading or degraded wiring.

j) **Energy Audits:** Regular energy audits are often a part of green building maintenance programs. These audits can identify excessive voltage drops and recommend upgrades or corrective actions to improve energy performance.

10.5.5 Power factor correction

Power Factor Correction (PFC) in green buildings is a critical aspect of improving energy efficiency. Power Factor (PF) is a measure of how effectively electrical power is being used in a system. It is the ratio of real power (measured in watts) to apparent power (measured in volt-amperes). A power factor closer to 1 indicates efficient power use, while a lower power factor indicates that a portion of the electrical energy is wasted. In the context of green buildings, improving power factor is not only about optimizing energy use but also reducing energy

losses and improving the performance of electrical systems.

10.5.5.1 Understanding Power Factor:

Following are the terminologies related to the power which need to be understood

- a) **Real Power (Active Power):** The actual power that performs useful work, such as running motors or lighting.
- b) **Reactive Power:** Power that oscillates back and forth, often due to inductive loads like motors, transformers, and other devices that create magnetic fields.
- c) **Apparent Power:** The combination of real and reactive power. Apparent power is the total power supplied to the system, but not all of it does useful work.

A poor power factor (typically below 0.8) indicates a lot of wasted energy, which can lead to higher electricity costs, overloading of transformers and other electrical equipment, and reduced system efficiency.

10.5.5.2 Why Power Factor Correction Matters for Green Buildings

- a) **Reduce Energy Wastage:** By correcting the power factor, energy losses in the electrical system are minimized, resulting in less wasted electricity.
- b) **Lower Utility Bills:** Poor power factor can lead to higher electricity bills, as many utility companies in several countries charge extra fees for low power factor. Correcting this can save on energy costs.
- c) **Optimize Electrical System Performance:** High-quality electrical systems run more efficiently, reducing the load on equipment, transformers, and other infrastructure. This results in a longer lifespan for the equipment and fewer maintenance costs.

10.5.5.3 How Power Factor Correction Works

Power factor correction typically involves the addition of capacitors or synchronous condensers to the electrical system. These devices provide reactive power locally, compensating for the inductive loads (such as motors and transformers) that cause the power factor to drop.

- a) **Capacitors:** These are the most common form of power factor correction. Capacitors offset the inductive effect of loads by supplying leading reactive power to the system. This reduces the overall amount of reactive power drawn from the grid.
- b) **Synchronous Condensers:** These are rotating machines that can adjust the amount of reactive power they supply or absorb, offering more dynamic control over power factor correction.
- c) **Active Power Factor Correction (APFC):** This is a more sophisticated technique that involves electronic devices (such as power factor correction controllers) that dynamically adjust the power factor by controlling the amount of reactive power in real-time.

10.5.5.4 Power Factor Correction in Green Buildings

- a) **Energy-efficient Design:** Green buildings often incorporate energy-efficient lighting (e.g., LED lights), HVAC systems, elevators, and motors. While these devices are energy-efficient, they can still create a low power factor if they are not managed properly. Including PFC as part of the electrical system design helps balance this.
- b) **Smart Metering and Monitoring:** Modern green buildings often use smart building systems to monitor energy consumption and adjust operations dynamically. This data can be used to identify areas with poor power factor and trigger corrections in real time.
- c) **Renewable Energy Sources:** Green buildings that incorporate solar or wind power may have variable power generation. Power factor correction can help balance the supply of power from these renewable sources with the building's demand, ensuring efficient energy use.
- d) **Building Automation Systems (BAS):** BAS can optimize power factor by regulating electrical loads based on real-time consumption and demand, reducing peak power consumption, and adjusting power factor correction equipment as necessary.

10.5.5.5 Challenges and Considerations

While power factor correction is highly beneficial, there are a few considerations:

- a) **Overcorrection:** Excessive power factor correction (more than necessary) can lead to problems like voltage instability or resonance, which could damage equipment.
- b) **Cost:** Initial investment in power factor correction equipment, particularly if high-end active power factor correction devices are needed, could be a consideration in the budget.
- c) **Ongoing Monitoring and Maintenance:** To ensure continued optimal performance, PFC equipment may require ongoing monitoring, maintenance, and adjustment.
- d) **Variable Frequency Drives (VFDs):** VFDs control the speed of motors (such as in pumps or fans) to adjust electrical consumption based on the current demand. This can help balance loads across different times of the day.

10.5.6.2 Integration of Renewable Energy Sources

- a) **Solar Power:** Solar panels generate electricity, reducing the reliance on grid power. Load balancing systems can manage the flow of energy from solar panels, either by using it directly or storing excess energy in batteries for later use.
- b) **Wind Power and Other Renewables:** For buildings with wind turbines or other renewable sources, load balancing can adjust energy consumption based on the availability of power, ensuring efficient use of renewable energy.

10.5.6 Load balancing

Electrical load balancing refers to distributing the electrical load evenly across all phases of the electrical system (especially in three-phase systems), ensuring no single phase is overloaded. In the context of green buildings, load balancing is integral to integrating energy-efficient technologies, renewable energy systems, and energy storage systems without causing strain on the building's electrical infrastructure. Electrical load balancing is crucial in green buildings to optimize energy use, enhance efficiency, and integrate sustainable technologies. The goal is to evenly distribute the electrical demand across the system to avoid overloading circuits, reduce energy waste, and minimize costs, while also supporting the building's environmental objectives.

10.5.6.1 Key Components of Load Balancing

- a) **Smart Meters and Load Monitoring:** Smart meters enable real-time tracking of energy consumption. These systems can monitor loads at different times and locations within the building, allowing for better distribution.
- b) **Advanced Control Systems:** Use of Energy Management Systems (EMS) to control when and how electrical loads are drawn from the grid or renewable sources. These systems optimize load balancing by adjusting lighting, HVAC, appliances, and other electrical systems in response to real-time demand.
- c) **Energy Storage Systems:** Batteries or other forms of energy storage (like thermal storage) can smooth out fluctuations in energy demand and supply. They store excess energy when demand is low and discharge when demand spikes.

10.5.6.3 Demand Response Programs

In some regions, buildings can participate in demand response programs, where they adjust their load based on grid signals (like when there's a peak demand in the grid). Load balancing within a green building can be designed to allow for flexible load reduction or shifting, helping the grid maintain stability while saving the building owner money.

10.5.6.4 Energy Management Software

- a) **Building Management Systems (BMS):** BMS integrates all of the building's electrical systems and uses data analytics to optimize energy consumption. These systems can implement advanced algorithms to predict demand and make real-time adjustments, automatically balancing loads.
- b) **AI and Machine Learning:** Advanced AI systems can learn patterns of energy use within the building and forecast peak demand periods. This allows the building to adjust its electrical load dynamically to minimize the chance of overloading circuits or wasting energy.

10.5.6.5 Electric Vehicle (EV) Charging Integration

With the rise of electric vehicles (EVs), many green buildings now include EV charging stations. Smart load balancing systems can ensure that the addition

of EV charging does not overwhelm the building's electrical system by coordinating when and how much electricity is used for EV charging in relation to other loads.

10.5.6.6 Designing for Load Balancing

- a) **Zoning and Circuit Design:** Properly zoning the building's electrical load and designing circuits that are capable of supporting different zones can help balance demand. For example, critical systems like lighting and HVAC can be placed on separate circuits from non-essential systems.
- b) **Sub-metering:** Sub-metering involves tracking the electrical usage of individual systems or sections of the building, helping to pinpoint areas where load balancing is needed or where energy-saving improvements can be made.

10.5.6.7 Future Trends and Technologies

- a) **Microgrids:** A microgrid is a localized energy grid that can operate independently or in coordination with the main grid. In green buildings, microgrids can help balance energy loads between the building, its energy storage system, and renewable energy sources.
- b) **Energy-as-a-Service (EaaS):** With the advent of EaaS platforms, building owners can optimize energy use, including load balancing, through a subscription-based service. These platforms use cloud-based solutions to manage and distribute energy efficiently.

10.5.6.8 Benefits of Load Balancing in Green Buildings

- a) **Reduced Energy Consumption:** Load balancing minimizes wasteful energy usage, lowering electricity consumption and helping the building meet sustainability goals.
- b) **Extended Equipment Life:** By preventing overloading and reducing peak demand spikes, load balancing can extend the life of electrical equipment, reducing maintenance costs and downtime.
- c) **Cost Savings:** Optimal load management can help reduce energy costs by avoiding peak demand charges and optimizing energy use during off-peak hours.
- d) **Enhanced Grid Stability:** For buildings participating in demand response or using

renewable energy, load balancing can support grid stability by reducing the strain on the local electrical grid.

10.5.7 Harmonic Distortion:

Harmonic distortions are the distortion of sinusoidal waveform of current and voltage in electrical system. Total Harmonic Distortion (THD)% is generally used to describe how badly the waveform is distorted. Higher the THD%, more the effects in electrical system.

10.5.7.1 Causes of harmonic distortions:

Modern buildings, especially, critical and commercial facilities such as Hospitals, Data centers, Airports, Hotels, and offices are now flooded with electronic non-linear loads and controls for example LED lights, VFDs, UPS, drivers etc. Those non-linear loads draw current in non-linear way and causes distortion in current waveform then further causing distortion in voltage waveform of the overall electrical system.

10.5.7.2 Effects of harmonic distortion in electrical systems:

A significant level of harmonic distortion in the electrical system of the facility can create a whole range of problems and some of them are as follows:

- Overheating of Transformers, Cables, Circuit breakers, Capacitor banks, Motors, and Fuses wasting significant amount electrical energy to heat. Premature failure and reduced lifespan of electrical devices because of the overheating. In worst cases, risk of fire hazards also possible.
- Nuisance trip of breakers and fuses due to the added heat and harmonic loading questioning the reliability of protection system.
- Unstable operation of backup generators and generator overload due to harmonic overloading.
- Unstable operation sensitive electronic devices that require a pure sinusoidal AC wave especially in hospital facilities.
- Flickering of lights.

10.5.7.3 Harmonic Distortion corrective measures:

The best solution is achieved with harmonic mitigation technologies that are able to mitigate the harmonic distortion below (5% THDv) & (10%

THDi) acceptable harmonic distortion by most of the electrical standard IEEE (519-2014 table1&2). During design phase these mitigation techniques results most beneficial

- Selection of electrical equipment's that generates less harmonic distortion (<5%)
- Oversizing of electrical equipment's to handle the harmonic loading such as oversizing of power cables (Ref. IS 732 annex-v), backup generators etc.
- If non-linear load is more than 20% of total load, a harmonic analysis is recommended and installation of harmonic filters is suggested.

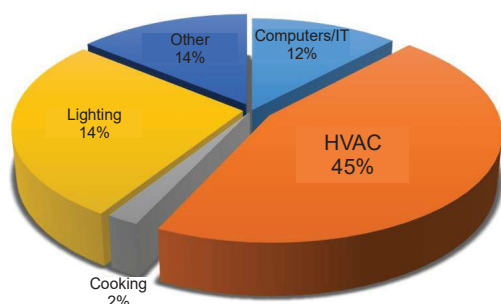
10.6 Energy Efficient Technologies, Equipment, and Appliances

There is tremendous development in energy efficient technologies, equipment, and appliances during past few decades due to awareness of people and market economy, as well. Depending upon the requirement of the project/client, available budget, and considering long-term economy, there is disposal of array of energy efficient technologies, equipment, and appliances to choose from. The following are the latest development in energy

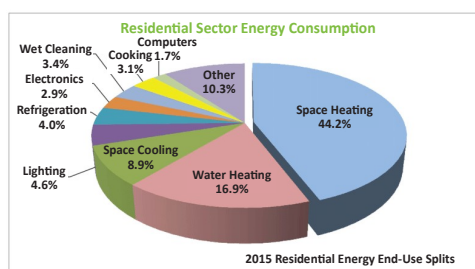
efficient technologies, which are gaining popularity day by day: Solar panels, Cool roofs, High-tech fenestration, Exterior insulation, Air sealing, home energy management systems (HEMS), Smart plug load controllers, Smart motion sensors, LED lights, Smart thermostats, Energy-efficient insulation, Smart HVAC vents, High-efficiency heat pumps, Smart appliances, and Electric vehicle (EV) chargers.

The given piecharts illustrate the energy usage in residential and commercial buildings. It shows about half of the portion of the energy consumption in commercial buildings is in HVAC system whereas one third of it is in lighting. Similarly, in residential sector, it is apparent that the energy consumption lies in water heating and space heating/cooling i.e. 70% of the total consumption. Due to this weightage, energy efficient design for HVAC and Lighting should be taken as major concern which are already dealt in previous sections. Besides, Washing & Drying Machines; Refrigerators; Dishwashers; and Cooktops comes in next row of the appliances which consumes much energy. Hence, these appliances also should be chosen from the energy rated products that helps saving remarkable amount of energy and resources.

Figure 75: Energy consumption pattern



b) Commercial sector energy Consumption



a) Residential sector energy Consumption

In recent years, unhealthy competition has developed in this sector. The manufacturers, entrepreneurs, and private sector organizations have started to greenwash the technology, equipment, and project as a whole. Greenwashing is a practice of making false or misleading claims about a product, service, or company's environmental impact. The term is a combination of "green", which implies environmental benefits, and "whitewashing", which means glossing over wrongdoings. Therefore, we must be very careful when choosing energy-efficient technologies, equipment, and appliances. In this connection, the Energy Rating System can be very helpful in achieving the true energy efficiency of the project.

10.6.1 Energy Rating

To ensure energy efficiency of the electrical appliances, designer should select the appliance considering the energy ratings. An energy efficiency rating is a score that measures how well a building or appliance uses energy. An energy rating label provides information about an

appliance's energy efficiency and running costs. More and more countries are recognizing the many benefits of energy efficiency standards and labelling (EES&L) programs to effectively reduce energy bills, drive product innovation, create jobs and reduce CO₂ emissions cost. EES&L programs for appliances and equipment now operate in more than 120 countries around the world and provide the cornerstone of most national energy efficiency and climate change mitigation programs. Followings are three popular energy rating system:

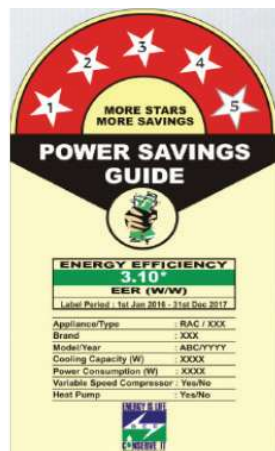
Figure 76: Popular Energy rating systems



a) Energy Star, USA.



b) Energy Label, EU & UK



c) BEE Star Label, India.

- ENERGY STAR** is the trusted, US government-backed symbol for energy efficiency of appliances. Generally, a product is with star or non-star. Products that earn the ENERGY STAR label meet strict energy-efficiency specifications set by the U.S. Environmental Protection Agency (EPA).
- EU Energy Label** is energy consumption labelling scheme established by EU Directive. The energy efficiency of the appliance is rated in terms of a set of energy efficiency classes from A to G on the label, A being the most energy efficient, G the least efficient. The labels also give other useful information to the customer as they choose between various models. In an attempt to keep up with advances in energy efficiency, A+, A++, and A+++ grades were later introduced for various products; since 2010.
- The Bureau of Energy Efficiency (BEE)** in India implemented 2006 the Standard & Labeling Pro-

gramme of BEE Star. The rating is based upon 1 to 5 stars. It is recommended to use at least a 3-star rated appliance, with the best being a 5-star rating. The BEE Star labelling is also very popular in Nepal.

10.7 LED Lamp

Lighting systems are a significant part of a building's energy load; therefore, selection of an energy efficient lamp also plays pivotal role on achieving energy efficiency of a building design. Design considerations should aim at minimizing this load through strategic placement of lighting fixtures, use of low-power LED (Light Emitting Diode) lamps, and employing automatic controls. IEC 62471 provides guidelines on safe use of LED lighting, while ASHRAE 90.1 specifies lighting power density (LPD) limits for various building types. For instance, the LPD for an office building is capped at 0.82 W/sq.ft.

These days, the use of LED lamp is getting pretty common. We can hardly buy CFL or incandescent lamp in market. Therefore, it is high time to stop advocating that we have to use LED light instead of CFL or incandescent lamp to achieve energy efficiency. Instead, we have to pay attention towards quality of LED bulb, illumination calculation as per function of the premises, and use of lighting controls with various type of sensors.

In order to choose good quality LED luminaire components, some of the important considerations are as follows:

- **LED Chips** are made up of semi-conductor layers that allow the protons and electrons to flow freely, converting electrical current into light. LED chips is the primary component of a lamp and should be chosen among well-known manufacturers. The reliability of LED chips is very important, and they should also offer higher efficiency for better energy efficiency and balanced brightness.
- **LED driver** is a power regulating circuit, which is responsible for regulating and supplying the ideal current to the LED. The LED driver rectifies the AC and lowers the level to suit the requirements. This means converting the high AC mains voltage which ranges from 120 Volts to 277 Volts, to the required low DC voltage. LED drivers may be either internal or external.

An internal LED driver is housed inside the bulb assembly. An external driver, on the other hand, is housed in a separate location. The compatibility of the LED driver with the LED chips and the design of the luminaire is also very important; in case there is no compatibility, the performance of the light may deteriorate. The efficiency of the LED driver is very important factor. A good LED driver should have high efficiency, which means that it converts the input power to LED lights with minimal losses. The efficiency of the LED driver is measured in terms of a percentage, and it is important to choose an LED driver with high efficiency to ensure energy efficiency and cost savings. Generally, LED driver efficiency can be 95-98%.

- The **heat sink** should be made out of materials that offer good thermal conductivity so that the heat is effectively dissipated, and it helps in increasing the lifespan of LEDs.
- The **optics and lenses** of the luminaire should also be made of high-quality material, and they should offer the desired light coverage based on the pattern of light distribution.
- The **housing materials** should be made of material that is durable and offers corrosion resistance. Also, to ensure that the luminaire has the right IP rating, the materials should be up to the mark so that the luminaire is protected from dust and moisture.
- The **color perception** of the LED lights must be accurate, and to ensure that LEDs that have a high CRI (Color Rendering Index) need to be chosen. CRI is a measurement of how natural colors render under an artificial white light source when compared with sunlight. The index is measured from 0-100, with a perfect 100 indicating that colors of objects under the light source appear the same as they would under natural sunlight.
- During selection of LED luminaires, it is necessary to verify their compliance with the technical **Certification** like Energy Star, CE (Conformite Europeenne), and UL (Underwriters Laboratories) and **Code** (Harmonized System code, Photometric code, and Arduino code).
- The **brand** or manufacturer the LED luminaries is very important. It is required to check that it carries a history of manufacturing reliable and high-quality LED lights with a good reputation.

It is recommended to select an LED light and other electrical appliances based upon the labeling of the product. One can choose from 3-star to 5-star or from C class to A+++ class, depending upon the requirement of the project and budget.

10.8 Day Lighting system

Use of daylight is one of the pivotal components of the Green Building Design, as it is directly related to electrical energy saving and occupant's comfort. On the one hand, we have to strive to achieve maximum use of daylight, but on the other hand, we have to be very careful that it may lead toward overheating of a building. It is very important to follow 'window to wall ratio' (WWR) and 'wall to floor ratio' (WFR) considering climatic condition of the building site.

The use of daylight in buildings by different sunlight applications/systems, whether passive (traditional) or active (innovative), is more than just an alternative or supplement to electric lighting, as it has many benefits in terms of economic, environmental, and health that cannot be gained from artificial lighting. Properly designed day lighting system can achieve an energy saving of 10 to 40 %. The applications of daylighting strategies can also maintain the occupants of interiors in a good health. The replacement of artificial light with natural light can improve the psychological well-being. It can enhance productivity by 15%, and reduce the absenteeism by 15%. On the physical side, natural light can improve vitamin D, visual system, and sleep quality, reduce the possibility of cancer and abnormal bone formation, to being able to make the brain produce serotonin hormone (responsible for relieving pain, providing energy and making us feel happy) and melatonin hormone (responsible for regulating the body's internal clock or circadian rhythm).

10.8.1 Factors Affecting Daylight

- a) **Latitude:** Determines the sun's angle and daylight hours, influencing the design of shading devices.
- b) **Climate:** Affects the availability of sunlight; cloudy regions will rely more on diffused skylight.
- c) **Building Orientation:** Optimal positioning and orientation of a building can maximize daylight exposure while minimizing heat gain.

10.8.2 Measuring Daylight

- a) **Lux:** A unit of illuminance measuring light intensity as perceived by the human eye. It is equal to one lumen per square meter.
- b) **Foot-candles:** An older unit of illuminance, equivalent to one lumen per square foot.
- c) **Daylight Factor (DF):** The ratio of indoor illuminance to available outdoor illuminance, expressed as a percentage. A well-lit office space, classroom kitchen typically has a daylight factor of 2%, lobbies, lounges, living room: 1%, and corridors, bedrooms: 0.5%.
- d) **Useful Daylight Illuminance (UDI):** Range of daylight levels that are useful and comfortable for occupants, typically between 100 and 2000 lux.

10.8.3 Key Principles of Daylighting Design

- a) **Window Placement and Design:** Proper window design and placement are critical in maximizing natural daylight while controlling glare and heat gain. Please refer to APPENDIX 2 for 'Design Method of Shading Devices for Openings'
- b) **Optimal Window-to-Wall Ratio:** A balanced ratio ensures sufficient daylight penetration without excessive heat loss or gain.
- c) **High-Performance Glazing Options:**
 - i. *Tinted Glass:* Reduces glare and solar heat gain.
 - ii. *Low-Emissivity (Low-E) Glass:* Minimizes heat transfer while maximizing light transmission.
 - iii. *Electrochromic Glass:* Adjusts transparency dynamically to control glare and heat.

10.8.4 Daylighting strategies

There are two types of daylighting strategies: Passive (Traditional) and Active (Innovative).

10.8.4.1 Passive (Traditional) Day Lighting System

Passive Day Lighting System is a common daylighting strategy which includes windows, skylights, laylights, atriums, and more. As the name suggests, passive daylighting strategies are static, non-moving features that do not require the use of mechanical components or systems to collect and reflect light into a building. Passive daylighting

encompasses some of the oldest lighting strategies and may be realized in a variety of ways:

A. Windows & Doors

- i. Of all the passive daylighting strategies, windows are the most widespread. Windows vary considerably in the amount of daylight they admit depending on glaze type (which dictates the window's visual light transmittance), treatment, and the grade of glass, as well as the physical positioning and orientation of the window itself.
- ii. Clerestory windows are one of the most useful types of windows for passive daylighting purposes, as they sit high up on a wall—above eye level—and allow ambient sunlight to reach deeper into a room. When opened, clerestory windows also serve as passive ventilators and can help better regulate interior temperatures.
- iii. To a lesser extent, doors may serve as daylighting devices, provided they are composed primarily of glass (such as those found in most commercial structures).

B. Atriums

Traditionally, atriums can be glass-walled or glass-roofed—are designed to illuminate large, centralized spaces in buildings. Atriums are typically several stories high and provide both daylight and a visual link to the outside world, resulting in a dynamic lighting feature that is both impressive and practical. Atriums offer some measure of daylight to adjacent areas not directly beneath them, but this is largely restricted to the uppermost floors. Atria can help to illuminate lower stories, but only if the floor and walls are capable of reflecting light.

C. Skylights

Another popular form of daylighting is skylights—or those large glass panes that may be used to form all or a portion of a building's roof space. Skylights permit light to enter a structure and also offer protection from the elements. Depending on the type of skylight, they may also serve ventilation purposes. Operable skylights, for example, feature a hinged sash and can be opened in much the same way a traditional window may be opened. This is also true of retractable skylights, which sit on steel tracks that allow them to roll open.

Figure 77A: Example of Traditional Daylighting Method

Fig. 3. Some of traditional daylighting applications/methods; (A) Window and light shelf, (B) Prismatic glazing, (C) Holographic films, (D) Skylight, (E) Metal louver, (F) Translucent roof, (G) Roof monitor, (H) Roller blind, (I) Clerestory window, (J) overhangs, and (K) Assembling glazing [50-53].

– Walid Aniss Aissa, Aswan University

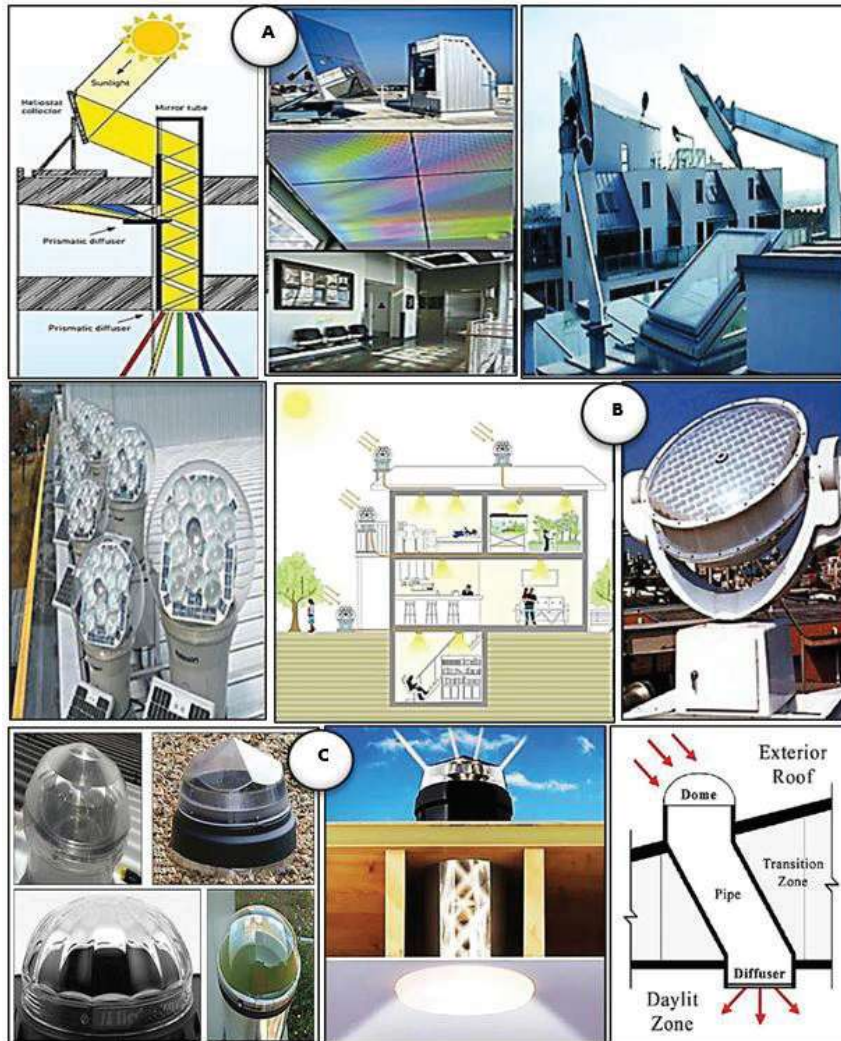
D. Translucent Walls

In terms of daylighting strategies, there are two main types of translucent walls: glass brick and panels. Glass brick walls are the oldest form of translucent wall and are composed of thick glass blocks stacked atop one another. Color and level of translucency can vary depending on how the blocks are prepared. Alternatively, large translucent panels—be they glass or polycarbonate—may

be used to form or cover walls on a larger scale. Translucent panels are favored due to the fact that they diffuse the sunlight they receive into glare-free daylight that can be used to illuminate interiors (while also providing privacy in the process).

While designing Atrium, Skylight, and Translucent wall, we have to be very careful that excess area can lead towards overheating of the premises.

Figure 77: Innovative daylighting



E. Light Tubes

These devices function similarly to skylights as they are installed on rooftops to harvest sunlight, transfer it through a highly reflective tube, and distribute it evenly throughout an interior space by way of a diffuser.

10.8.4.2 Active (Innovative) Day Lighting System:

As the name indicates, this system is mechanical in nature and use mechanisms to actively track or follow the sun throughout the day to collect and provide sunlight. Most active daylighting systems use a series of mirrors and lenses to direct and concentrate light into distribution tubes. There are two types of active solar tracking systems:

A. Closed-loop Systems

A closed-loop daylighting system uses sensors or lenses to track the sun throughout the day. Designed to be fully illuminated at any given moment, the sensors are directed at the sun and have a very limited field-of-view—when the sun moves and a sensor becomes shaded, the system moves accordingly.

B. Open-loop Systems

Open-loop daylighting systems do not rely on sensors to track the sun. Instead, they use a pre-programmed mathematical sun chart that details the sun's location at any given date and time for a specific location.

Using this information, the system follows the sun throughout the day without the aid of external factors.

Chapter 11

Indoor Air Quality and Comfort

- >> Nature of Problem
 - >> Sick Building Syndrome (SBS) and Building Related Illness (BRI)
 - >> Magnitude of the problem
 - >> Reasons for IAQ Problem
 - >> Preventive Strategies for maintaining Indoor Air Quality
 - >> Recommended environment criteria
 - >> Interdisciplinary approach
-

SICK BUILDING SYNDROME



Source: <https://www.isomat.eu/company/quality-innovation/technical-articles/sick-building-syndrome/>

11

Indoor Air Quality and Comfort

Indoor air quality refers to the condition of the air inside a building directly impacting occupants' comfort and health. Before the COVID-19 pandemic, the intent of GBD was to provide a basic level of indoor air quality that would support the health and well-being of building users. In this post-pandemic era, the value of Indoor Air Quality has increased, as viruses and bacteria can easily transmit through air. The GBGN aims to achieve high indoor air quality throughout a building's lifetime by employing diverse strategies including source elimination or reduction, active and passive building design and operation strategies and human behavior interventions.

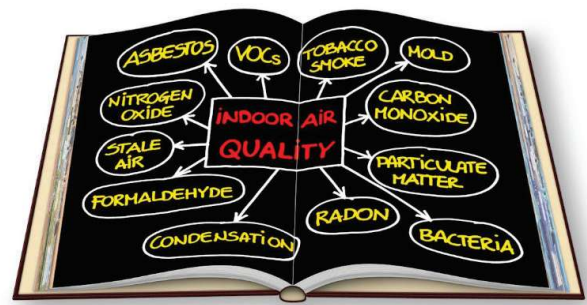
11.1 Nature of Problem

People spend approximately 90% of their time in enclosed spaces such as homes, offices, schools or other building environments. During this time, inhalation exposure to indoor air pollutants can lead to a variety of negative short- and long-term health and well-being outcomes that can vary in severity. Maintaining Good IAQ benefits in many ways: it reduces the risk of respiratory issues, allergies, and other health problems, enhances occupant comfort by providing a pleasant indoor environment, improves productivity and performance, and extends the life span of building materials and HVAC systems.

11.2 Sick Building Syndrome (SBS) and Building Related Illness (BRI)

A sign of an SBS and BRI is that occupants are experiencing health issues, such as frequent coughs, headaches, itchy skin, watery eyes, and other problems. In most cases, the 'syndrome' or problem originates from the building's indoor air quality (IAQ), i.e., the air is serving as a pathway to causing those health issues. The effect of a sick building also depends on personal factors such as immunity. However, even a person with higher immunity may feel discomfort or reduced productivity when one enters a building with SBS due to the foul atmosphere. SBS is a complex

phenomenon, and although a number of potential contributory factors have been suggested, much of the evidence is circumstantial. SBS may result from the simultaneous combination of a number of contributory factors that include: (HSE, 1992)



- (1) Physical aspects, such as inadequate ventilation;
- (2) Thermal discomfort;
- (3) Low humidity,
- (4) Air pollution including airborne organic matter;
- (5) Poor lighting flickering lights, glare etc.; and
- (6) Others are personal factors, such as low morale and general dissatisfaction with working conditions, immunity etc.

Certain features of the indoor environment might contribute to SBS including high temperatures, low or high relative humidities, inadequate ventilation, insufficient fresh air supply, poor lighting and a lack of negatively charged ions.

Air quality also influences thermal comfort, i.e. people's perception of satisfaction with an indoor climate. This encompasses aspects such as room temperature, humidity, air velocity, radiant heat, clothing and level of activity. The link between sick building syndrome and thermal comfort lies in the fact that poor thermal conditions indoors can increase the risk of SBS symptoms occurring. If the room temperature is too high or too low, if the humidity level is too high or too low or if there is a strong draught, it can lead to problems. The probability of

sick building syndrome symptoms increases when people spend time in an environment where there is poor thermal comfort.

11.3 Magnitude of the problem

Apart from the above-mentioned minor health issues, more severe health outcomes can include asthma attacks, infection with Legionella bacteria and carbon monoxide poisoning. Exposure to air pollutants, such as Volatile Organic Compounds (VOCs), ozone, particulate matter, carbon monoxide and others has been shown to increase the risk of respiratory and cardiovascular diseases, in addition to causing thousands of cancer deaths annually. Besides, random exposure is the second leading cause of lung cancer, after tobacco use.

11.4 Reasons for IAQ Problem

The IAQ problem could result from one or a combination of factors. These can be categorized as follow:

- 1) **Chemical contaminants:** Most indoor air pollution originates from sources inside the building. For example, adhesives, carpeting, upholstery, manufactured wood products, copy machines, pesticides, and cleaning agents may emit volatile organic compounds (VOCs), including formaldehyde. Environmental tobacco smoke contributes high levels of VOCs, other toxic compounds, and respirable particulate matter. Research shows that some VOCs can cause chronic and acute health effects at high concentrations, and some are known carcinogens. Low to moderate levels of multiple VOCs may also produce acute reactions. Combustion products such as carbon monoxide, and nitrogen dioxide, as well as respirable particles, can come from unvented kerosene and gas space heaters, woodstoves, fireplaces and gas stoves. Other contaminants are lead paint, settled lead dust, VOC (Volatile Organic Compound) in building construction materials, and asbestos matter.

Outdoor air entering a building can be a source of indoor air pollution. For example, pollutants from motor vehicle exhausts; plumbing vents, and building exhausts (e.g., bathrooms and kitchens) can enter the building through poorly located air intake vents, windows, and other
- 2) **Biological contaminants:** Bacteria, molds, pollen, and viruses are types of biological contaminants. These contaminants may breed in stagnant water that has accumulated in ducts, humidifiers and drain pans, or where water has collected on ceiling tiles, carpeting, or insulation. Sometimes insects or bird droppings can be a source of biological contaminants. Physical symptoms related to biological contamination include cough, chest tightness, fever, chills, muscle aches, and allergic responses such as mucous membrane irritation and upper respiratory congestion. Legionella, an indoor bacterium has caused both Legionnaire's Disease and Pontiac Fever.
- 3) **Dampness:** The majority of dampness is from the ground due to poor damp proofing at the plinth level. Other damp penetration is from the roof and wall.

11.5 Preventive Strategies for maintaining Indoor Air Quality

- 1) **Monitoring indoor air quality:** The quality of indoor air should be monitored continuously. Humidity and temperature can be monitored using a hygrometer. Special VOC measurement devices are used to measure VOCs while the CO₂ concentration is monitored by means of CO₂ measurement devices.
- 2) **Sufficient ventilation:** This includes bringing in outdoor air and exhausting indoor air to dilute and remove indoor contaminants. Ensuring that there is sufficient ventilation, ventilation systems and air filters should be maintained and cleaned on a regular basis in order to ensure good air quality. ASHRAE Standard 62.1-2019, "Ventilation for Acceptable Indoor Air Quality," provides guidelines and requirements to ensure acceptable indoor air quality, focusing on ventilation and contaminant control.
- 3) **Source control:** Building materials, furnishings and cleaning products chosen should be ones that only release low emissions of VOCs and other harmful chemicals. Potential sources of contaminants that cause sick building syndrome should be cleaned or removed.

- 4) **Humidity management:** Indoor humidity can be influenced in the short term by carrying out regular ventilation. For a permanently positive effect, various air-conditioners can be used to ensure a healthy level of humidity. If the level of humidity is constantly too high, dehumidifiers can help. If the level of humidity is too low, humidifiers are the right choice.
- 5) **Air filtration:** Air cleaning filters are designed to remove pollutants from indoor air. By properly filtering the facility's air of harmful particles, it can improve the indoor environment and breathe cleaner air. It also reduces pollen and other allergens, which can cause asthmatic attacks and allergic reactions. Air filters serve several essential functions within air conditioning systems, contributing to:
- i. Improved indoor air quality,
 - ii. Protection of HVAC equipment,
 - iii. Enhanced energy efficiency.

Air filtration is another method that can assist in reducing indoor virus concentration when the existing ventilation system cannot provide an adequate air change rate. Air filtration methods are divided into the followings:

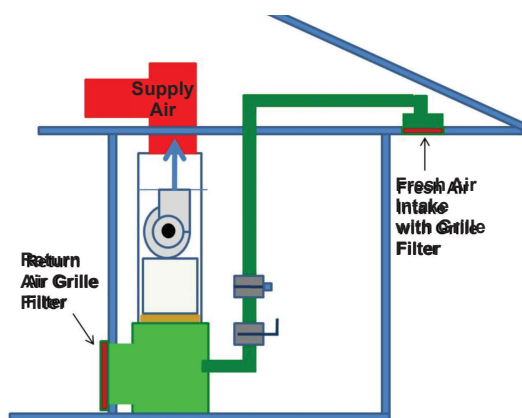
- i. **In-duct devices (filters):** In-duct devices work for the entire house but function only during the operation of an air-handling system where they are installed.
- ii. **Portable air cleaners (PACs):** PACs can be operated and positioned in a room with the

flexibility to target the problem areas and have received increasing attention in recent years. PACs are devices designed to clean and sanitize the air in a home. They remove impurities in the air, including dust, smoke, odors, and other air pollutants.

The particle-removal performance of air filtration devices is evaluated by the clean air delivery rate (CADR), which is the product of the single-pass efficiency and airflow rate. According to particle filtration efficiency, air filters are divided into four types:

- I. **Pre filter:** The filtering material is mounted on the outer frame made of stainless steel, aluminum alloy or galvanized frame. The pre-filter material includes glass fiber filter or other metal mesh.
- II. **Medium filter:** The filtering material is mounted on the outer frame made of aluminum alloy, galvanized, plastic or paper frame. The medium-efficiency filter material includes glass fiber, chemical fiber and PP (polypropylene).
- III. **High-Efficiency Particulate Air (HEPA) filter:** The filtering material is mounted on the outer aluminum alloy frame, multi-layered frame or galvanized steel frame. Mostly glass fiber and chemical fiber are used for the filtering medium. Latest development of HEPA filter medium is PTFE (polytetrafluoroethylene) fiber.

Figure 78: Air filtration



a) In-duct filter



b) Portable air cleaners

Among these, HEPA filters have shown excellent performance in removing expiratory aerosols and are most widely adopted in the market. It has at least 99.97% efficiency for removing particles in the range of 0.15 to 0.2 μm , which is the most penetrating particle size (MPPS) due to the combined effect of different mechanisms of particle capture. (HSE, 1992) & (EPA, 1991)

11.6 Recommended environment criteria

1) **Fresh air supply:** Most forced ventilation systems operate with a large proportion of extracted air being recycled after conditioning; i.e. filtered, heated or cooled or humidified as necessary. A proportion of fresh/make-up air is always required. The source of fresh air supply should be sited such that it is not contaminated by external sources such as road traffic, industrial processes and other ventilation system discharges.

Fresh air supply rates of 8 liters per second per person would be sufficient for respiratory and odor-dilution needs. Supply rates ranging from 12 liters per second per person for some smoking, to 32 liters per second per person for areas of heavy smoking, are necessary to maintain acceptable atmospheres. Where high fresh air supply rates are required but the existing ventilation system is incapable, without excessive modification, of supplying the higher rates, then provision of a separate dedicated smoking area/rest room with an integral extract ventilation system may be a reasonable solution.

2) **Air movement:** Lack of perceptible air movement within the workplace can promote a feeling of stuffiness, whereas excessive air movement will produce complaints of draughts. Air velocities should normally be approximately 0.1 to 0.15 meters per second and up to 0.25 meters per second during the summer.

3) **Healthy relative humidity:** A key factor in maintaining healthy indoor air is regulating relative humidity within optimal ranges. High humidity levels, above 70%, can foster mold growth, which is associated with allergic reactions and respiratory conditions such as asthma [1]. On the other hand, very low humidity, below 40%, can lead to dry indoor air, causing discomfort and health issues like respiratory infections, including tonsillitis, pharyngitis, or

bronchitis. Extremely low levels, under 20%, may exacerbate problems such as skin irritation, eye discomfort, and static electricity buildup, indirectly contributing to poor air quality through off-gassing and the presence of airborne dust and fibers.

To promote healthy indoor environments, it is recommended to maintain relative humidity levels between 40% and 70%, with adjustments toward the lower end of this range at higher temperatures to ensure comfort and health. Sustainable building practices prioritize the use of breathable materials, which naturally regulate indoor humidity and help mitigate condensation and mold risks. When combined with efficient ventilation systems and proper insulation, these materials contribute to maintaining optimal indoor air quality, supporting both occupant well-being and energy efficiency. Sustainable buildings designed with these principles not only reduce health risks but also foster a more resilient and comfortable living and working environment.

11.7 Interdisciplinary approach

The GBGN seeks to implement holistic design strategies to promote clean air and minimize human exposure to harmful contaminants, in order to maximize benefits to productivity, well-being and health. It can be achieved by fostering collaboration among HVAC, Sanitary, Electrical, and Civil engineers to mitigate IAQ problem at the very beginning of the design phase.

It is important to define indoor air quality levels that minimize risk to human health. The World Health Organization (WHO) and other regulatory bodies, such as the U.S. Environmental Protection Agency (EPA) identify a list of "criteria" air pollutants. They have established permissible levels for such criteria pollutants based on epidemiological studies showing the relationships between concentrations of these pollutants, duration of exposure and health risks. Achieving the goal of clean indoor air as defined by permissible levels, requires the joint efforts of both professionals and building users in the implementation of adequate approaches. (WELL V-2, International WELL Building Institute, California, US)

Chapter 12

Sustainable Construction Practices

- >> Pre-construction
 - >> During construction
 - >> Post construction
-



Source: <https://greensutra.in/sustainable-construction-practices>

12

Sustainable Construction Practices

The term ‘construction practices’ refers to all the activities in construction ranging from pre-construction stage (site selection, preparation of design and specifications, tendering) to construction and post-construction stage. Since all the aspects relating to the designing and decision making prior to on-site activities are mostly covered by previous chapters, this section mainly focuses on the activities which includes green procurement, construction site preparation and management, construction operation to site clearance and handover. The following are the objectives of sustainable construction practice:

- It reduces the environmental impact of construction activity on the environment and people maintaining high level of efficiency in operation.
- It applies green construction technologies.
- It ensures Health and safety.
- Construction of waste management.
- Energy efficiency in the work place and site operations.
- Water efficiency in construction.

12.1 Pre-construction

12.1.1 Procurement

The green building design concept should be primarily incorporated into the design documents which will be materialized through the builder. Effective execution of the design is possible only if the procurement of the construction contractor is proper. Hence, it is crucial that all the risks and issues be considered during the procurement process for successful execution of the green building projects. Strategies for hiring contractors, construction managers, sub-contractors and vendors should be as follows:

12.1.1.1 Selection of Contractors/sub-contractors

- Highlight all the requirements for sustainable green practices in construction works on-site within the tender documents.
- Include selection criteria to identify capable contractors for executing green building projects.
- Allow sub-contractor in bidding asking for the specific qualification requirement that the firm has successfully completed work on sustainable/green projects in the past. This criterion for selection helps mainstream the green thinking among the contractors.
- Arrange regular training sessions to the contractors and sub-contractors on Green Building Construction and facilitate the registration of trained contractors.

12.1.1.2 General Conditions for Bidding

- Require submission of detailed safety plan from contractors/sub-contractors implementing key items.
- Allow only non-toxic cleaning agent for building final cleaning activities.
- Require detailed site recycling plans, including incentives/penalties to ensure execution.
- Allow no smoking on-site during construction.
- Require ‘kick-off’ sustainable construction education for all on-site work force.
- Incorporate works for green/sustainable building in specifications.
- Provision for joint SCP monitoring event and require attendance at its meetings by all site personnel.
- Require periodic education training sessions for both engineers and workers.
- Implement incentives for site staff for implementation of sustainable practices.

- Green/Sustainability focal person requirement from each team (i.e. contractor/sub-contractor/designer etc.)
- Require Energy Star for temporary and permanent building equipment.

12.1.2 Site and Environment

- **Know the site** – Identify vegetation, wildlife habitat, climate, solar pattern, temperature, prevailing wind direction, humidity, precipitation and dominant weather patterns peculiar to the site.
- **Preserving the natural environment** of the site complying with the prevailing environment regulations.
- **Prepare detailed Construction site management plan** with thoughtful consideration for following aspects:
 - **Workers’ facilities** - Infrastructures (accommodation, dining, toilets etc.) for workers
 - **On-site drainage Plan**
 - **Waste management plan**
 - **Plan for transportation and vehicular movement**
- **Site security** – Necessary measures for site security such as site barricading, safety signage, surveillance system, guard’s facility etc.

12.2 During construction

12.2.1 Demolition and abatement

- **Disassemble buildings to maximize the materials salvaged.** Outline the dedicated area for de-construction and disassembly.
- **Prevent contamination** - Take proper precaution to prevent contamination of the site during demolition and removal of hazardous materials.

12.2.2 Site works

- **Existing site conditions**
 - Maintain the existing topography and terrain. Minimize the area to be cleared or graded.
 - Minimize the removal of trees and vegetation. Mulch or compost on-site vegetation that has been removed from site.
 - Sell lumber of trees needing to be cleared. Do not slash and burn.

- Plant areas cleared or graded with native species of the site.

- **Preserve pervious land**

- Reduce the size of impervious areas. Disconnect them when possible.
- Limit equipment traffic and staging locations to areas that will eventually be paved.

- **Logistic management**

- Organize lay down material in order of use (i.e. next material to be used, closest to work activities)
- Protect materials from rain and groundwater (use tarps, stage under protected structures etc.)
- Stage materials and equipment on non-pervious surfaces.
- Place hot kettles and other fume producing equipment with concern for wind direction and neighboring environments.

- **Storm water management**

- Assess stormwater flow prior to any construction milestones as well as when any significant changes are made to the site.
- Disperse stormwater according to the site work plans. Maintain the natural drainage of the site as per the initial site analysis.
- Manage erosion control measures by slowing down surface water (e.g., maintain wetlands, construct sediment ponds, pervious pavement etc.)
- Treat wastewater before it leaves the site to maintain the water quality.

- **Atmosphere**

- **Dust control** - Use proper dust control measures along circulation path such as watering, dust control polymers, dust barriers etc.
- **Noise control** - Apply Noise control measures if noise had to be prevented from the sensitive areas in surroundings.

- **Traffic management**

- Design proper circulation plan for material movement and management

- If it is in public building where service is being provided during construction, clear demarcation of service route and construction route should be planned.
 - Designate truck and vehicle cleaning area.
- **Prevent erosion and ground failure**
- By predicting changes in the site's previous surface throughout the construction. Develop an erosion and sediment pollution control plan.
 - Implement dewatering and erosion control methods during underground work.
 - Protect perimeter of building with metal plates or some other appropriate forms of ground protection.
- **Prevent contamination**
- Eliminate any and all possibilities of contamination to site's natural water resource (chemical, runoff pollution, spillage etc.).
 - Check equipment and vehicles for hazardous leaks frequently throughout the project.
 - Re-fuel equipment only in dedicated areas. Protect against spillage.
 - Use eco-friendly hydraulic fluid in elevators. Apply proper waterproofing in elevator pits to protect ground contamination.
- **Apply green construction technologies**
- **Prefab assemblies** - Give preference to off-site prefabricated assemblies (e.g. precast concrete) over site-fabricated assemblies which require more space for assembly and increase site disturbance.
 - **Construction equipment** – In the projects with larger site area, give preference to tower cranes with large booms and controlled positions over mobile cranes. Reduce the site impact of machinery and cranes.
- **Electrical works**
- Protect conduit trenches against storm water and erosion.
 - A full cutoff lighting fixture, one with no direct up light at all, and with essentially no glare. In such fixture, all the light is used, none is wasted, hence energy is conserved. This also prevent adverse effect of bad lighting and light pollution.
- **Health and safety**
- It is to ensure health and safety of the construction workers at site which construction managers have to consciously plan to improve the quality of life of construction workers. For this, the following should be considered:
- Minimize the use of harmful products on-site to reduce harmful effects on workers.
 - Increase awareness of harmful products and ingredients in order to protect workers and minimize use.
 - Increase the use of personal safety apparatuses.
 - Avoid using asbestos, lead based paint, mold etc. which are harmful to workers, occupants and the environment.
 - Use respiratory protection when necessary.
 - Take appropriate measures to minimize and eliminate mold.
 - Be aware of the danger of carbon monoxide poisoning from running gas-powered engines in enclosed spaces.
 - Minimize products containing VOC and other off-gassing material including glues, solvents, cleaning materials, and aerosol sprays.
 - Allow adequate ventilation during activities such as painting, laying carpeting and other activities where workers are exposed to high concentrations of off-gassing materials.
 - Make it mandatory for the the contractor to prepare and implement site safety survey, plan and an emergency action plan. Besides, it should include a fire control plan, safety patrol, regular meeting plan and a plan for educating workers on health and safety, etc.
- **Energy efficiency in the work place and site operations.**
- Maximize the use of photovoltaic panels for construction and warning signage where applicable.
 - Shut off temporary lighting systems when not in use.
 - Use energy efficient lamps and other electrical appliances.

■ Efficient technologies

Use of sustainable technology reduces paper waste for on-site work activities and generates efficient project communications. These technologies save time and effort during on-site work.

- Use of electronic devices such as e-paper for reading documents, CCTV camera, mobile field devices, short-range radio technology, web conferencing system, digital signature system etc.
- Use efficient software for material tracking, electronic punch lists, and pocket version of CAD.

■ Water efficiency in construction

Construction sites can be made more water-efficient by using water-saving devices, monitoring water usage, and educating the workforce:

- **Water-saving devices:** Install low-flow taps, sensor-controlled taps, dual-flush toilets, and hoses with triggers, and waterless urinals in site offices.
- **Monitor water usage:** Install water meters to track the amount of water being used.
- **Educate the workforce:** Encourage staff to report leaks and wastage.

- **Use rainwater:** Collect rainwater for storage and reuse in tanks, ponds, dams, swimming pools, or underground tanks. Rainwater can also be used for flushing toilets and cleaning floors.
- **On-site treatment:** Re-use effluent on site rather than discharging it.

■ Construction and demolition waste management

- Waste and scraps produced through construction work should be disposed properly with application of the principle of recycle and reuse.
- Monitor waste and recycling designated areas to enforce responsible practices.

12.3 Post construction

- Regular maintenance with proper plan and budget.
- Implement waste reduction programs during use of the building.
- Performance monitoring: Monitor the building's performance in terms of green building parameters (energy, water use, and indoor air quality).
- Restoration of dereliction caused to the site.

Chapter 13

Commissioning and Building Performance Tracking

- >> Building Commissioning
- >> Building Performance Tracking
- >> Building Performance Tracking complements Commissioning



13

Commissioning and Building Performance Tracking

Commissioning and building performance tracking are two distinct processes but are crucial and closely interlinked to ensure the achievement envisioned by the project. This section provides a brief introduction to commissioning and building performance tracking, and their procedures.

13.1 Building Commissioning

Commissioning is defined as “a quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria.” (Kubba, 2010). It is a holistic process that begins at a project’s inception, i.e., the beginning of the design process, and proceeds through design, construction, startup, inspection, testing, balancing, acceptance, training, and an agreed warranty period. Commissioning is a quality assurance-based process that provides preventive and predictive maintenance plans, tailored operating manuals, and training procedures for users to follow. The main function of the commissioning process is to ensure that the HVAC & R systems and associated controls, domestic hot water systems, lighting controls, renewable energy systems (e.g., PV, wind, solar) and other building systems meet the owner’s performance requirements and operate at maximum efficiency. Successful project commissioning can significantly reduce operating and maintenance costs, provide healthier occupant conditions, and

facilitate upgrades. Commissioning usually begins with reviewing the documentation and design intent for reference. Performance testing of components is conducted upon first arrival at the job site and again after installation is complete. Providing maintenance training and manuals is typically the final step of commissioning.

13.1.1 Types of Commissioning

There are basically three types of commissioning.

- a) **Initial commissioning:** This is for new buildings, ensuring systems are designed, installed, and calibrated to run according to the project requirements and design specifications from the very start.
- b) **Re-commissioning:** Aimed at buildings that have previously undergone the commissioning process, re-commissioning is conducted to ensure that a building continues to meet its original design and operation objectives, usually after a significant change in use, occupancy, or major system upgrades.
- c) **Retro-commissioning:** This process applies to buildings that have never been commissioned. It seeks to improve the efficiency of an existing building’s systems to reduce energy consumption and costs, enhance system controls, and improve occupant comfort.

Figure 79: Outline of commissioning process



13.1.2 Commissioning Authority

The owner should appoint a commissioning authority who plays key role in the process. He/she leads the commissioning team comprising senior specialists who direct and oversee the process. The commissioning authority should be retained early in the programming phase of the project.

13.1.2.1 Commissioning Authority Qualifications and Certification

It is strongly recommended that an independent party be the Commissioning Authority, i.e., neither the contractor, A/E, nor the CM. The Commissioning Authority should be motivated solely by the needs of the owner and the facility user and should not normally be competitors of the A/E or contractors. Chosen individuals should be highly specialized in the types of facilities and systems to be commissioned. Because of the level of technical oversight that is expected, individuals should be a licensed professional engineer, or have applicable experience in specialized systems/facilities being installed, in addition to extensive experience in the design, optimization, remediation, and acceptance testing of applicable systems, as well as training and building manual preparation.

13.1.2.2 Commissioning Authority's Responsibilities

A. Construction Phase

- a) Conduct Commissioning meetings.
- b) Review relevant project documentation such as shop drawings, reports, product data, record drawings, O & M data, etc. for compliance and to ensure system functionality.
- c) Installation to be monitored and periodically inspected.
- d) Review and approve startup checklist forms.
- e) Attend progress meetings as required to observe progress and assist other parties, facilitate the Commissioning process, and help expedite completion. The Commissioning Authority however does not direct work nor approve/accept materials, systems, or equipment if it is separate agent.
- f) Compile O & M information and systems overview and format the O & M manuals.
- g) Witness selected test startups and equipment training sessions.

B. Acceptance Phase

- a) Verify, test, adjust, and balance by spot check all lab reports, control component. Calibration and equipment performance certifications (test 100 percent of key systems or test sample percentage).
- b) Analyze all trend logs.
- c) Test systems and equipment to verify correct system operation and that they are functioning as per specifications, including failure and safety modes.
- d) Review training plan and coordinate training activities between the O & M staff and the contractors/vendors to assure the training is appropriate for the staff.
- e) Record commissioning procedures and provide Commissioning report with testing documentation.
- f) Verify that contractors/vendors provide proper O & M material (fan curves, pump curves, operating parameters, etc.), and not just equipment mounting information.
- g) Follow through to ensure that commissioning issues are resolved.

C. Warranty Phase

- a) Talk with building users to identify any problem areas that have developed after building acceptance.
- b) Assist owner in resolving outstanding issues with contractor and design firms.
- c) Provide follow-up training to O & M staff, especially if new staff that was assigned to the building did not previously receive vendor training.
- d) Check building performance and conduct seasonal testing on systems.

13.1.3 The Commissioning Team

The commissioning team is a joint team consisting of individuals (representative of owners, users, occupants, design professionals, contractors, operations and maintenance staff) who, through coordinated actions, are responsible for implementing the commissioning process and are led by the Commissioning Authority.

13.1.4 The commissioning plan

The commissioning plan provides guidance in the execution of the commissioning process and preferably commences early in the design process. It forms part of the bid and contract documents and is binding on the contractor; it also outlines many of the contractor’s responsibilities, procedures, and tasks throughout the Commissioning process.

A sample of the structure of the commissioning plan is shown below which should be customized to the specific projects.

13.1.5 Commissioning Checklist

It is the checklist prepared based on the standards and guidelines stipulated in above sections. It can be developed for all three stages: Pre-construction, Construction and Completion. Two clauses in the checklist will be designated mandatory and obligatory. Mandatory clauses are checked during any sign-off stage whereas obligatory clauses will be checked only during the evaluation process for green rating.

13.2 Building Performance Tracking

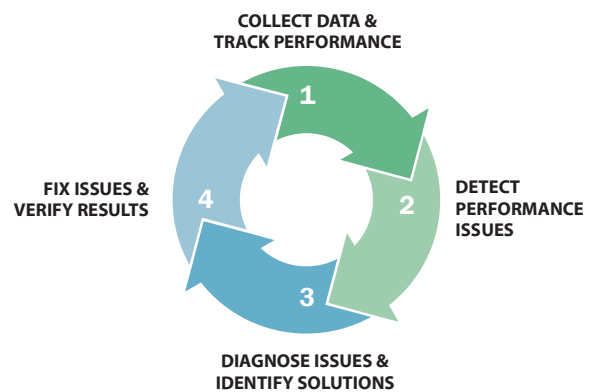
Building performance tracking is a process of continuous improvement. At its core, it monitors how efficiently a building meets its occupants’ needs, which includes maintaining:

- comfortable temperatures and humidity,
- ventilation requirements,
- lighting requirements.

It is a long-term strategy fueled by the hardware, software, people, and processes that make optimization a regular part of building management. The fundamental process consists of four steps:

1. collect data and track performance,
2. detect performance issues
3. diagnose issues and identify solutions.
4. fix issues and verify results.

Figure 80: Fundamental 4-step process of building performance tacting



During the tracking, different instances such as sensors drifting out of calibration, changes in building use, and adjustments in control sequences might affect how well systems work together. This can result in occupant complaints and increased energy costs. Hence, it is a proactive strategy for maintaining up-to-date occupant comfort. Besides,

Table 14 : A sample of the structure of the commissioning plan

Introduction	Purpose and general summary of the plan.
General Project Information	Overview of the project, emphasizing key project information and delivery method characteristics.
Commissioning Scope	The commissioning scope including the building assemblies, systems, subsystems, and equipment that will be commissioned on this project.
Team Contacts	Project specific commissioning team members and contact information.
Communication Plan & Protocols	Documentation of the communication channels to be used throughout the project.
Commissioning Process	Detailed description of the project specific tasks to be accomplished during the planning, design, construction and tenant occupancy stages with associated roles and responsibilities.
Commissioning Documentation	List of commissioning documents required to identify expectations, track conditions and decisions, and validate/certify performance.
Commissioning Schedule	Specific sequences of events and relative timeframes, dates, and durations.

it provides evidence of how well the building is performing.

Building performance tracking is done to address two main elements:

- 1) System Tracking – HVAC, lighting systems etc.
- 2) Resource Tracking – Electricity, water, gas etc. keeping submeters.

13.3 Building Performance Tracking complements Commissioning

Building performance tracking serves as an ideal complement to building commissioning (existing and retro- and re-commissioning). These tracking helps verify the system performance and their achievements of goal which is one of the most important functions of the building commissioning. Data and its analysis results provide the basis for further actions during commissioning, such as repair and maintenance, replacement, training, updating documentation, system upgrade, etc.

To implement this, the three Ps 'People, Process and Performance' tracking tools need to ensured.

1. **People** - Commitment from all building management stakeholders at all levels of the organization. Without people instituting goals and rewards, and managing day-to-day performance, tools may fall into disuse making success difficult.
2. **Process** – It is the management processes that support building performance tracking. It includes:
 - Allocation of the financial and labor resources
 - Well-defined reporting and accountability
 - Specific language to support building performance tracking in contracts with tenants and service providers
 - Incentives for building performance tracking job execution
3. **Performance Tracking Tools** - Software tools and the associated hardware are the backbone of building performance tracking. Performance tracking tools range from simple manual recording and free online benchmarking tools to sophisticated portfolio management tools.

- a. **Sensors:** Install sensors to measure temperature, humidity, CO2 levels, brightness, and presence. These sensors can be connected to a management system to adjust environmental conditions according to occupant needs.
- b. **Data loggers:** Data loggers are electronic instruments that record measurements at set intervals over a period of time. They have data storage and one or more sensors which can be deployed indoors, outdoors or underwater. They can record data for up to years at a time, unattended. The stored data can be downloaded and accessed for visualization through software/apps.

Figure 81: Datalogger equipment



- c. **Submeter** – To measure the consumption of electricity, water, gas and other resources, submeters should be used in different sections of the system.
- d. **Air quality sensors:** Monitor, measure, and report environmental factors like temperature, humidity, pressure, and air pollutants.
- e. **Digital panel meters:** Track humidity, pressure, and more. They can also monitor electrical equipment performance by displaying voltage and current information.
- f. **Occupancy sensors:** Detect people's presence to regulate temperature control or air conditioning usage.
- g. **Air velocity sensors:** Measure air velocity, temperature, humidity, and pressure.
- h. **Thermometers:** Provide accurate temperature readings.
- i. **Humidity indicator strips or color cards:** Inexpensive humidity-monitoring devices.

Appendix 2:

Design Method of Designing Shading devices for openings

Solar radiation is one of the most important parameters affecting thermal comfort. The amount of solar radiation and visible light transmitted inside a building depends on the orientation of the opening, type of glazing used, and the fenestration design. This solar radiation penetration can be favorable or extremely unfavorable depending on the prevailing climatic conditions, season, time of day, building function and space use (occupant's activity). Therefore, in hot tropical climates, it is necessary to minimize the penetration of solar radiation into buildings through strategies such as appropriate building orientation (along the east–west axis), adequate sizing of openings (window to wall ratio), proper location of openings (facing north and south), careful selection of glazing properties and appropriate solar protection using shading devices.

To avoid unwanted heat gains and glare, windows should ideally be shaded throughout daylight hours in the tropics. However, this may lead to impractical overhang and fin designs especially in the early morning and late afternoon hours when the sun is low in the sky. Hence, more practical and reasonable design solutions must be developed. Solar control through shading devices is most effective when designed specifically for each façade as the time and duration of solar radiation vary with the sun's position in the sky—its altitude and azimuth.

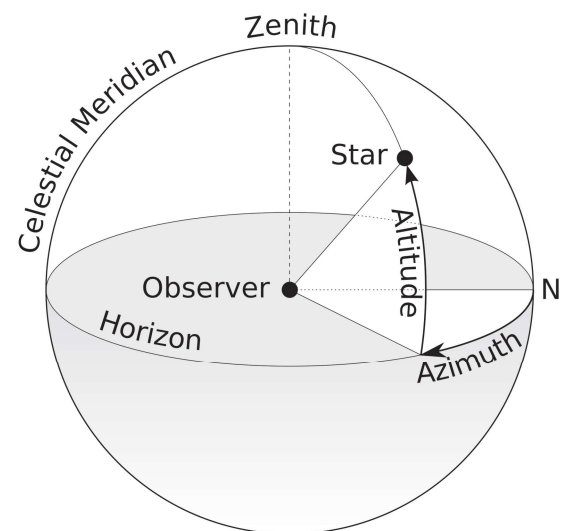
To control heat gain and provide adequate shading, it is important to have a good understanding of solar geometry, solar radiation and solar energy in various hours of the day and across different seasons is essential. This knowledge is important for designing passive heating and cooling strategies, orienting buildings effectively, understanding seasonal changes within the building and its surroundings, and developing appropriate shading devices. This section explains how to use solar charts and sun path diagrams and defines the sizes of shading devices for windows on different orientation in different latitudes at selected cut-off times.

Solar Geometry

The earth's movement around the sun creates different solar paths characterized by variable heights and lengths depending on the time of the year and latitude. The sun's apparent movement follows an east-to-west trajectory. Its position at different times of the year can be found through two angular coordinates namely (Figure 55):

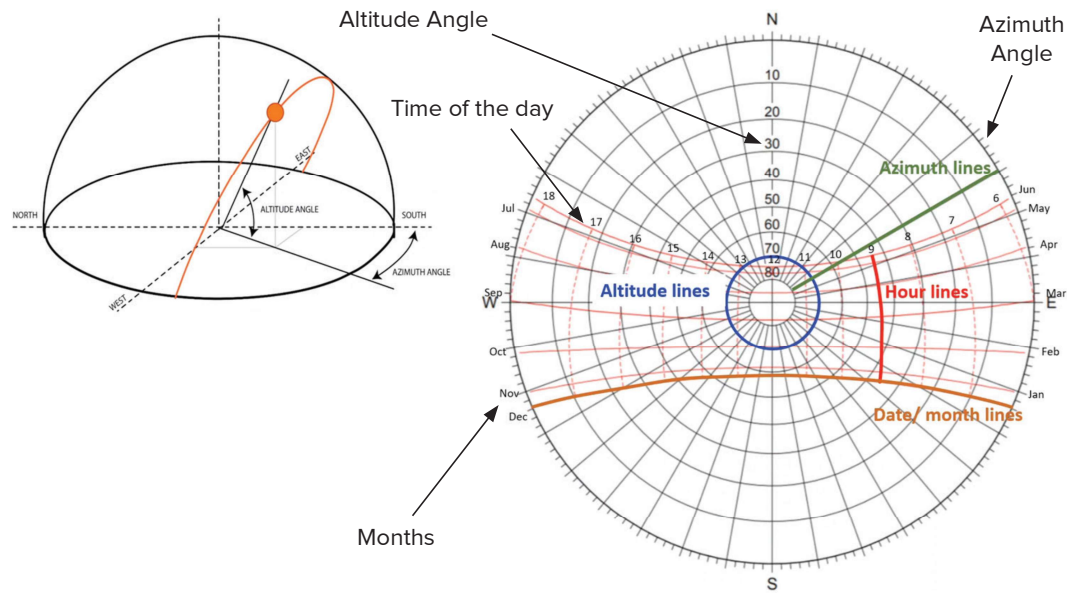
- **Solar altitude** β , represented by the angle between the line joining the center of the sun with the observation point and the horizontal plane
- **Solar azimuth** α , which is the angle measured on the horizontal plane, from the north-pointing coordinate axis to the projection of above joining line.

Figure 2: Angular coordinates of the sun



Sun Path Diagrams

Sun path diagrams conveniently represent the Sun's changing position in the sky throughout the year. These diagrams are projected onto a horizontal plane, on which the four cardinal points (North, South, West and East) are marked. The plane consists of concentric circles and radial lines (Figure 2). The Sun's position at any time of the day can be plotted on the horizontal plane. It is, therefore, possible to develop specific diagram for any latitude.

Figure 3: Method of using Sun Path diagram

The values of solar altitude β are represented by the circumferences (outermost corresponds to $\beta = 0^\circ$, horizon, while the center corresponds to $\beta = 90^\circ$, zenith). The values of solar azimuth α are indicated by the radial lines, and can be read out as the angular distance from the north-pointing coordinate axis. Sun Path Diagrams are available online (See Box 2).

Design steps

The following steps may be used to determine the appropriate size of the shading devices:

- 1. Determine the overheated period** - The dates and times when shading is desired is determined using average hourly temperature data of the place. Several online tools can be used to determine this parameter as shown in **Error! Reference source not found.** Time and month that have temperatures beyond comfort zone and needs shading is marked on the Sun path diagrams (Solar charts can be acquired from weblinks as shown in *Box 1*).
- 2. Find out azimuth and altitude of the Sun** - Use the appropriate Sun path diagram (suitable for the location in question) to obtain the azimuth and altitude of the Sun at each time of the cut-off periods.

- 3. Calculate Horizontal shadow Angle (HAS) and Vertical Shadow Angle (VSA)** - Determine the HSA and VSA using equation 1 & 2 or using the solar protractor.
- 4. Design the shading device:** Calculate the size of overhands and fins using the equation 3 to satisfy the performance specifications.

1.1.1 Design of Shading Device

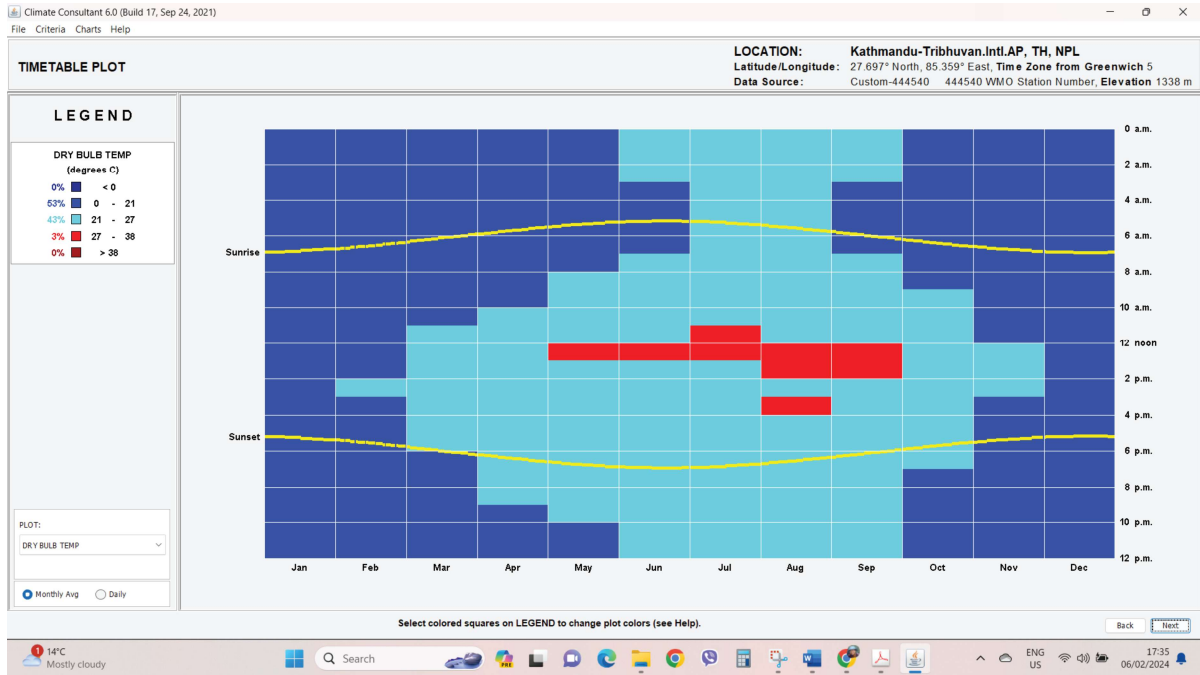
When attempting to shade a window, two important shadow angles must be considered: the horizontal shadow angle (HSA) and vertical shadow angle (VSA). These angles express the sun's position in relation to a building façade at a given orientation and can be used to show the performance of a given shading device based on the shade it produces.

Horizontal Shadow Angle (HSA) - The horizontal shadow angle (HSA) describes the performance of a vertical shading devices. It is the difference in azimuth between the sun's position and the orientation of the building façade under consideration (Figure 5.a). It can be calculated using the following equation:

$$\text{HSA} = \text{Azimuth angle } (\alpha) - \text{Wall azimuth (equation 1)}$$

Wall azimuth is the angle between the face of the wall of the building and the north direction. (Figure 5.a)

Figure 4: Time table plot from Climate Consultant



This is the time table plot from Climate Consultant. Climate Consultant is a free software available for download. This plot has months in X-axis and time of the day on Y-axis. The blue portion of the plot is cold and cyan colour is the comfort level whereas red colour indicates the overheated period. As an example, this plot indicates that sun shading is required from 11pm to 4pm from the month of May to September.

Download link: <https://climate-consultant.informer.com/6.0/>

Box 1: Web Sources for getting Sun path diagram

- <https://clima.cbe.berkeley.edu/>
- <https://www.suncalc.org/>
- <https://drajmarsh.bitbucket.io/sunpath3d.html>
- <https://drajmarsh.bitbucket.io/sunpath2d.html>
- https://www.sunearthtools.com/dp/tools/pos_sun.php?lang=en

Figure 5b: Designing vertical shading device

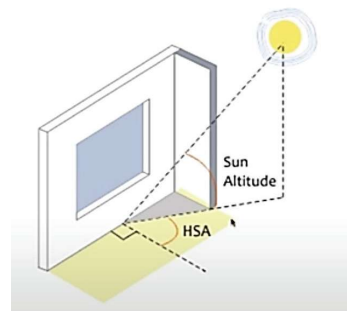


Figure 5a: Azimuth angle and wall azimuth angle

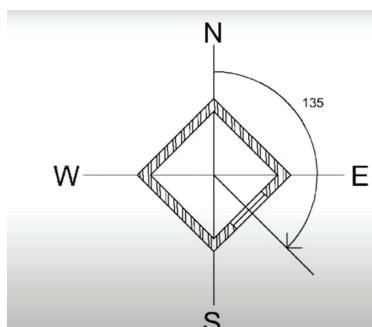
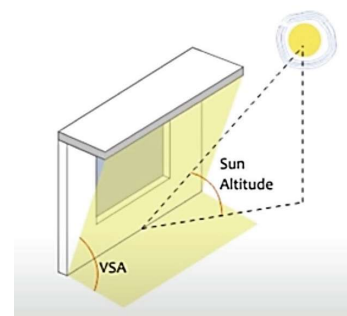


Figure 5c: Designing shading device



Vertical Shadow Angle (VSA) - The vertical shadow angle (VSA) is required for (or cast by) horizontal shading devices. It is the angle between a horizontal plane of the building façade under consideration and a tilted plane which contains the sun or the edge of the shading device (Figure 5.c). The following equation can be used to calculate VSA.

$$\tan(VSA) = \tan \beta \times \sec(HSA)$$

(Equation 2)

Calculating Shade dimensions

These two angles, HSA and VSA, can then be used to determine the size of the shading device required for a window. The depth of the overhang, its width (additional projection from the side of the window and the fins can be determined using the following equations

$$\text{Overhang Depth} = \frac{\text{Height}}{\tan(VSA)}$$

$$\text{Fin Depth} = \frac{\text{Width}}{\tan(HSA)}$$

(Equation 3)

Appendix 3:

Design Example of applying Mahoney Table in Gorkha town of Nepal

Mahoney Table mainly consists of the following four tables. This section explains the step-by-step method of using Mahoney Table in identifying climatic design strategies with an example of the Gorkha Town:

Table 1: Used to record the most essential climatic data

Table 2: Used for diagnosis of the climatic data and develop a series of climatic indicators.

Table3: Translates the above into performance specifications or sketch design recommendations.

Table 4: Gives recommendation for the design of building elements

Step-wise methodology

1. **Step 1** – Collect the climatic data from the data banks (Department of Hydrology and Meteorology)
2. **Step 2**
 - a. Fill in the 1st section of table 1 with the monthly mean temperature data.
 - b. Calculate Monthly mean range (MMR), Annual mean temperature (AMT) and Annual mean range (AMR).
 - c. Fill in the 2nd section of table 1 with monthly mean relative humidity.
 - d. Calculate average relative humidity and identify humidity group.
 - e. Fill in the 3rd section of the table 1 with rainfall and wind data.
3. **Step 3**
 - a. Fill in the first part of table 2 comparing the mean temperature with the comfort limits to identify the thermal stress with three variables: Hot (H), O (comfortable) and C (cold).
 - b. Identify occurrence of six pre-defined indicators in each month and count them to get total figures.
4. **Step 4**
 - a. Fill in the table 3 & 4 using the total numbers of the indicators and identify the recommended specifications and detailed recommendations.

Design example:**First Part of Table 1: Temperature**

Location: Gorkha	Longitude: 28.3°					Latitude: 84.7°				Altitude: 1000m				
Air temp.°C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	High	AMT
Monthly mean max.	20.6	24	28.6	31.5	32.1	32.5	31.2	31.3	30.7	28.6	24.8	20.7	32.5	27.9
Monthly mean min.	7.75	10.6	14.2	17.7	20	22.5	23.4	23.2	22.4	18	12.9	8.96	23.4	4.52
Monthly mean range	12.8	13.3	14.5	13.8	12	9.96	7.75	8.06	8.31	10.6	11.9	11.8	Low	AMR

1. Fill in the title block (location identification)
2. From meteorological records, enter the monthly mean maximum and mean minimum air temperature values in the first two lines.
3. Find the mean range for each month by deducting the mean minimum from the maximum values (second line from the first) and enter these in the third line.
4. In the separate box on the right, enter the highest of the twelve maxima and the lowest of the twelve minima respectively.
5. By adding these two values and dividing it by two, find the annual mean temperature and enter this value in the box marked AMT.
6. Find the difference between the lowest mean minimum value and the highest mean maximum value. Write it down in the box marked AMR (Annual Mean range).

Second Part of Table 1: Humidity

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly mean max am	93.3	88.6	76.9	74.9	80	85.5	91.2	91.5	92.5	94.5	96.1	96.1
Monthly mean min pm	68.4	62	55.3	53.6	61.9	70.1	78.7	79.4	80	78.2	79.6	78.9
Average	80.9	75.3	66.1	64.2	70.9	77.8	84.9	85.5	86.3	86.3	87.8	87.5
Humidity group	4	4	3	3	4	4	4	4	4	4	4	4

1. From meteorological records, enter the monthly mean maxima (early morning readings) and minima (early afternoon readings) of relative humidity (RH) as the first two lines.
2. Find the average humidity for each month by adding the above 2 values and dividing it by two. Enter these averages in the third line.
3. Establish the 'humidity group' for each month (1, 2, 3 or 4) according to the following categories and enter them in the fourth line.

Average RH	Humidity Group
Below 30%	Group 1
30-50%	Group 2
50-70%	Group 3
Above 70%	Group 4

Third Part of Table 1: Rainfall and Wind

Rainfall, mm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly mean max am	14.8	37.1	36	84.8	148	302	412	366	210	51.5	2.25	6.25
											Total	1670
Wind, Prevailing	N	NE	N	E	N	NE	NE	S	SE	E	N	N
Wind, Secondary	W	N	N	NE	S	SW	S	SE	SW	S	S	S

1. Enter the monthly average rainfall values (in mm) in the first line. Adding these twelve values, find the annual total rainfall and enter this in the box indicated.
2. In the last two lines, enter the prevailing and secondary wind directions for each month, on the basis of first and second peaks in published wind frequency tables or figures.

Table 2: Diagnosis**First part of the second table**

Diagnosis °C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly mean max	20.6	24	28.6	31.5	32.1	32.5	31.2	31.3	30.7	28.6	24.8	20.7
Day comfort, upper	27	27	29	29	27	27	27	27	27	27	27	27
Day comfort, lower	22	22	23	23	22	22	22	22	22	22	22	22
Thermal stress, day	C	O	O	H	H	H	H	H	H	H	O	C
Monthly mean min	7.75	10.6	14.2	17.7	20	22.5	23.4	23.2	22.4	18	12.9	8.96
Night comfort, upper	21	21	23	23	21	21	21	21	21	21	21	21
Night comfort, lower	17	17	17	17	17	17	17	17	17	17	17	17
Thermal stress, night	C	C	C	O	O	H	H	H	H	O	C	C

1. Enter the monthly mean minimum and maximum temperatures from table 1 in the first and fourth lines.
2. Find the upper and lower comfort limits for the day and night of each month, on the basis of the chart shown below, as defined by the 'annual mean temperature' and the 'humidity group' for each month. Enter these values in lines 2, 3, 5 and 6.
3. Compare the day comfort limits with the mean maxima and the night comfort limits.
4. With the mean minima, establish the nature of thermal stress by entering the following symbols in the last two lines:

H (hot)	If mean is above limit.
O (Comfort)	If mean is within limit.
C (cold)	Mean is below the limit.

Indicators

Comfort limit	AMT over 20°C		AMT 15-20°C		AMT Below 15°C	
	Day	Night	Day	Night	Day	Night
Humidity Group 1	26-34	17-25	23-32	14-23	21-30	12-21
Group 2	25-31	17-24	22-30	14-22	20-27	12-20
Group 3	23-29	17-23	21-28	14-21	19-26	12-19
Group 4	22-27	17-21	20-25	14-20	18-24	12-18

Meaning	Indicator	Thermal stress		Rainfall	Humidity group	Monthly mean range
		Day	Night			
Air movement essential	H1	H			4	<10°C
		H				
Air movement desirable	H2	O			4	
Rain protection necessary	H3			>200mm		
Thermal capacity necessary	A1				1-3	>10°C
Outdoor sleeping desirable	A2	H			1-2	
		H	O		1-2	>10°C
Protection from cold	A3	C				

Counting the indicators - There are six indicators. Among them, H1, H2, H3 are 'Humid Indicators' and A1, A2, A3 are 'Arid indicators'. Occurrence of these indicator is marked in the table below using the criteria of the indicators.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
H1	0	0	0	0	1	1	1	1	1	1	0	0	6
H2	0	1	0	0	0	0	0	0	0	0	1	0	2
H3	0	0	0	0	0	1	1	1	1	0	0	0	4
A1	0	0	1	1	0	0	0	0	0	0	0	0	2
A2	0	0	0	0	0	0	0	0	0	0	0	0	0
A3	1	0	0	0	0	0	0	0	0	0	0	1	2

Second part of the second table

1. Check from table 2 the thermal stress indices (day and night) and from table 1 the humidity group, the rainfall and the monthly mean range of temperatures against the definition of the indicators and place a tick in the line of the appropriate indicator where the month's data corresponds to the definition.
2. In the last column, show the number of months in which each indicator is applicable (the number of ticks in each line).

Table 3: Specifications

This table gives the designer the specifications resulting from the above indicators. Recommended specifications are grouped under eight headings.

Indicator totals from data sheet									
H1	H2	H3	A1	A2	A3				
6	2	4	2	0	2				
Layout									
			0-10			X	1	Orientation north and south (long axis east-west)	
			11-12		5-12				2
					0-4				
Spacing									
11-12							3	Open spacing for breeze penetration	
2-10						X	4	As above, but protection from hot and cold wind	
0-1							5	Compact layout of estates	
Air movement									
3-12						X	6	Rooms single banked, permanent provision for air movement	
1-2			0-5						7
	2-12						8	No air movement requirement	
0	0-1								
Openings									
			0-1		0		9	Large openings, 40-80%	
			11-12		0-1		10	Very small openings, 10-20%	
Any other conditions						X	11	Medium openings, 20-40%	
Walls									
			0-2			X	12	Light walls, short time-lag	
			3-12				13	Heavy external and internal walls	
Roofs									
			0-5			X	14	Light, insulated roofs	
			6-12				15	Heavy roofs, over 8h time-lag	
Outdoor sleeping									
				2-12			16	Space for outdoor sleeping required	
Rain protection									
		3-12				X	17	Protection from heavy rain necessary	

Table 4: Detailed Recommendations

Indicator totals from data sheet								
H1	H2	H3	A1	A2	A3			
6	2	4	2	0	2			
Size of opening								
			0-1		0		1	Large openings, 40-80%
					1-12	X	2	Medium openings, 25-40%
			2-5					
			6-10				3	Small openings, 15-25%
			11-12		0-3		4	Very small openings, 10-20%
					4-12		5	Medium openings, 25-40%
Position of openings								
3-12						X	6	In north and south walls at body height on windward side
1-2			0-5					
			6-12				7	As above, openings also in internal walls
0	2-12							
Protection of openings								
					0-2	X	8	Exclude direct sunlight
		2-12				X	9	Provide protection from rain
Walls and floors								
			0-2			X	10	Light, low thermal capacity
			3-12				11	Heavy, over 8h time-lag
Roofs								
10-12			0-2				12	Light, reflective surface, cavity
			3-12			X	13	Light, well insulated
0-9			0-5					
			6-12				14	Heavy, over 8h time-lag
External features								
				1-12			15	Space for outdoor sleeping
		1-12					16	Adequate rainwater Drainage

Appendix 4

Example of calculation of U-Value

General steps to calculate U-value

- i. Identify layers: List all layers of the wall, including their thickness (d) and thermal conductivity(k).
- ii. Calculate resistance, and R-values for each layer:
 $R_{\text{layer}} = d/k$
- iii. Add surface resistances (Refer to appendix 5.1 for more surface conductance values):
 - Outside surface resistance ($1/f_o$)= 0.075 m²K/W (Assuming external wall as south-facing severe exposure, surface conductance as 13.18 W/ m² K)
 - Internal surface resistance ($1/f_i$)= 0.123 m²K/W (Typical value of surface conductance is 8.12 W/ m² K)

- iv. Sum all resistances:

$$R_b = R_{\text{layer1}} + R_{\text{layer2}} \dots$$

- v. Calculate R_{a-a} using following formula.

$$R_{a-a} = \text{i.e. air to air resistance}$$

$$R_{a-a} = \frac{1}{f_o} + R_b + \frac{1}{f_i}$$

Where,

f_o = Outside surface conductance (m²K/W)

f_i = inside surface conductance (m²K/W)

R_b = summation of resistances of all the materials used (m²K/W)

- vi. Calculate U-value:

$$U = 1/R_{a-a}$$

Appendix 5:

A. Thermal properties of building and insulating materials (BEE, 2018)

S.N.	Type of material	Density (kg/m ³)	Thermal conductivity (w/m.K)	Specific heat capacity (kJ/kg.K)	Source
I. Building materials					
1	Solid burnt clay brick	1920	0.980	0.80	(1)
2	Solid burnt clay brick	1760	0.850	NA	(1)
3	Solid burnt clay brick	1600	0.740	NA	(1)
4	Solid burnt clay brick	1440	0.620	NA	(1)
5	Resource efficient (hollow) brick	1520	0.631	0.65	(4)
6	Fly ash brick	1650	0.856	0.93	(2)
7	Solid concrete block 25/50	2427	1.396	0.20	(4)
8	Solid concrete block 30/60	2349	1.411	0.30	(4)
9	Aerated autoclaved concrete (AAC) block	642	0.184	1.24	(4)
10	Cement stabilized soil block (CSEB)	1700	1.026	1.03	(5)
11	Cement stabilized soil block (CSEB)	1800	1.201	1.07	(5)
12	Cement stabilized soil block (CSEB)	1900	1.303	1.07	(5)
13	Dense concrete	2410	1.740	0.88	(3)
14	Reinforced concrete cement (RCC)	2288	1.580	0.88	(3)
15	Brick tile	1892	0.798	0.88	(3)
16	Lime concrete	1646	0.730	0.88	(3)
17	Mud Phuska	1622	0.519	0.88	(3)
18	Cement mortar	1648	0.719	0.92	(3)
19	Cement plaster	1762	0.721	0.84	(3)
20	Gypsum plaster	1120	0.512	0.96	(3)
21	Cellular concrete	704	0.188	1.05	(3)
22	AC sheet	1520	0.245	0.84	(3)
23	GI sheet	7520	61.060	0.50	(3)
24	Timber	480	0.072	1.68	(3)
25	Timber	720	0.144	1.68	(3)
26	Plywood	640	0.174	1.76	(3)
27	Glass	2350	0.814	0.88	(3)
28	Tar felt (2.3 kg/m ²)		0.479	0.88	(3)
II. Insulating materials					
1	Expanded polystyrene	16.0	0.038	1.34	(3)
2	Expanded polystyrene	24.0	0.035	1.34	(3)
3	Expanded polystyrene	34.0	0.035	1.34	(3)

4	Foam glass	127.0	0.056	0.75	(3)
5	Foam glass	160.0	0.055	0.75	(3)
6	Foam concrete	320.0	0.070	0.92	(3)
7	Foam concrete	400.0	0.084	0.92	(3)
8	Foam concrete	704.0	0.149	0.92	(3)
9	Cork slab	164.0	0.043	0.96	(3)
10	Cork slab	192.0	0.044	0.96	(3)
11	Cork slab	304.0	0.055	0.96	(3)
12	Rock wool (unbonded)	92.0	0.047	0.84	(3)
13	Rock wool (unbonded)	150.0	0.043	0.84	(3)
14	Mineral wool (unbonded)	73.5	0.030	0.92	(3)
15	Glass wool (unbonded)	69.0	0.043	0.92	(3)
16	Glass wool (unbonded)	189.0	0.040	0.92	(3)
17	Resin-bonded mineral wool	48.0	0.042	1.00	(3)
18	Resin-bonded mineral wool	64.0	0.038	1.00	(3)
19	Resin-bonded mineral wool	99.0	0.036	1.00	(3)
20	Resin bonded mineral wool	16.0	0.040	1.00	(3)
21	Resin-bonded mineral wool	24.0	0.036	1.00	(3)
22	Exfoliated vermiculite (loose)	264.0	0.069	0.88	(3)
23	Asbestos mill board	1397.0	0.249	0.84	(3)
24	Hard board	979.0	0.279	1.42	(3)
25	Straw board	310.0	0.057	1.30	(3)
26	Soft board	320.0	0.066	1.30	(3)
27	Soft board	249.0	0.047	1.30	(3)
28	Wall board	262.0	0.047	1.26	(3)
29	Chip board	432.0	0.067	1.26	(3)
30	Chip board (perforated)	352.0	0.066	1.26	(3)
31	Particle board	750.0	0.098	1.30	(3)
32	Coconut pith insulation board	520.0	0.060	1.09	(3)
33	Jute fiber	329.0	0.067	1.09	(3)
34	Wood wool board (bonded with cement)	398.0	0.081	1.13	(3)
35	Wood wool board (bonded with cement)	674.0	0.108	1.13	(3)
36	Coir board	97.0	0.038	1.00	(3)
37	Saw dust	188.0	0.051	1.00	(3)
38	Rice husk	120.0	0.051	1.00	(3)
39	Jute felt	291.0	0.042	0.88	(3)
40	Closed cell flexible elastomeric foam - NBR	40-55	0.043	1.20	(3)

Data Sources:

- (1) American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2009. 2009 ASHRAE Handbook (Fundamentals). Atlanta, United States: ASHRAE
- (2) Gourav K, et al. 2017. Studies into structural and thermal properties of building envelope materials. Energy Procedia 122: 104–108
- (3) Bureau of Indian Standards (BIS). 1987. Handbook on Functional Requirements of Buildings (Other than Industrial Buildings) SP: 41 (S & T) -1987. New Delhi: BIS.
- (4) Thermo-Physical-Optical Property Database of Construction Materials, U.S.- India Joint Center for Building Energy Research and Development (CBERD) and Ministry of New and Renewable Energy (MNRE). Available at http://www.carbse.org/wp-content/uploads/2017/10/Database-of-Construction-Materials_Oct17.pdf (accessed on 1 May 2018).
- (5) Balaji N C, et al. 2015. Influence of varying mix proportions on thermal performance of soil-cement blocks. Building Simulation Applications (BSA). 2nd IBPSA Italy Conference, Building Simulation Application - 2015 (BSA 2015). Available at http://www.ibpsa.org/proceedings/BSA2015/9788860460745_10.pdf (accessed on 1 May 2018)

B. Surface conductance and resistances

Surface	Conductance f W/ m ² degC	Resistance $1/f$ m ² degC/W
Internal surfaces (f_1) :		
Walls	8.12	0.123
Floor, ceiling, heat flow up	9.48	0.105
Floor, ceiling, heat flow down	6.70	0.149
Underside of roof	9.48	0.105
External surfaces (f_o)		
Walls, South facing:		
Sheltered	7.78	0.128
Normal		
Severe exposure	13.18	0.076
Walls, West, Southwest, South-east facing:		
Sheltered	10.00	0.100
Normal	13.18	0.076
Severe exposure	18.90	0.053
Walls, Northwest facing:		
Sheltered	13.18	0.076
Normal	18.90	0.053
Severe exposure	31.50	0.032
Walls, North, Northeast, East, facing:		
Sheltered	13.18	0.076
Normal	18.90	0.053
Severe exposure	81.20	0.012
Roofs:		
Sheltered	14.20	0.070
Normal	22.70	0.044
Severe exposure	56.70	0.018

C. Transmittance (U-value) of some constructions (in W/m²degC)

Type of construction	Value
<i>Walls</i>	
Brick:	
solid, unplastered 114 mm	3.64
plastered both sides 114 mm	3.24
Solid unplastered 228 mm	2.67
Plastered both sides 228 mm	2.44
Concrete, ordinary, dense:	
152 mm	3.58
203 mm	3.18
Stone, medium. porous:	
305 mm	2.84
457 mm	2.27
Brick, 280 mm cavity, fletton outer skin, common inner, inside plastered Brick with insulating boards, plastered:	1.70
25 mm corkboard	0.85
13 mm fibreboard	1.19
50 mm wood wool slab	0.85
Brick but 16 mm vermiculite plaster on the inside	1.47
Brick but rigid boards on battens on inside:	
13 mm asbestos board	1.19
13 mm fibreboard	0.95
50 mm strawboard, plastered	0.74
Brick but inner skin lightweight concrete blocks:	
100 mm aerated concrete blocks	1.13
100 mm clinker concrete blocks	1.30
Concrete block, cavity, 250 mm (100 +50 +100), outside rendered, inside plastered:	
aerated concrete blocks	1.19
clinker concrete blocks	1.08
Hollow concrete block, 228 mm, single skin, outside rendered, inside plastered:	
aerated concrete blocks	1.70
clinker concrete blocks	1.59
Corrugated asbestos cement sheets on steel frame	
+13 mm fibreboard	2.04
+50 mm straw or wood wool slab	1.19
+76 mm aerated concrete blocks	2.10
<i>Roofs, pitched</i>	

Corrugated asbestos cement sheets	7.95
+13 mm timber boarding	2.16
+50 mm straw or wood wool slab	1.25
+25 mm quilt on 13 mm boarding	0.85
Corrugated iron sheets or tiles on battens	8.52
+plaster ceiling	3.18
<hr/>	
Tiles or slates onboarding and felt with plaster ceiling'	1.70
<hr/>	
Aluminium deck, 13 mm fibreboard with two layers of bituminous felt	2.16
Aluminium deck,50 mm straw or wood wool slab	1.25
<hr/>	
<i>Roofs, flat</i>	
Reinforced concrete slab, 100 mm, screed 63-12 mm,3 layers bituminous felt As above - with insulation on the screed:	
25 mm cork	3.35
50 mm straw or wood wool slab	1.08
two 12 mm fibreboards	1.13
As above - but lightweight screed (in lieu of normal):	1.25
127 mm to 76 mm aerated concrete	1.36
127 mm to 76 mm foamed slag concrete	1.47
<hr/>	
Timber boarding, 25 mm on 178 mm joists with 3 layers of bituminous felt, plaster ceiling	1.82
<hr/>	
As above - with insulating slabs on boarding:	
25 mm cork	0.85
13 mm fibreboard	1.25
50 mm straw or wood wool slab	0.91
<hr/>	
Floors	
Concrete on the ground or hardcore fill	1.13
+grano, terrazzo or tile finish	1.13
+wood block finish	0.85
Timber board on joists, underfloor space ventilated on one side	1.70
+parquet, lino or rubber finish.	1.42
<hr/>	
Timber board on joists, underfloor space ventilated on more sides	2.27
+parquet, lino or rubber finish	1.98
+25 mm fibreboard underboarding	1.08
+25 mm corkboard underboarding	0.95
+25 mm corkboard under joists	0.79
+50 mm strawboard under joists	0.85
+double-sided aluminium foil. draped	1.42
<hr/>	
<i>Windows</i>	

Exposure South, sheltered:	
single glazing	3.97
double glazing, 6 mm space	2.67
double glazing 20 mm space	2.32
South normal, West, Southwest, Southeast sheltered:	
single glazing	4.48
double glazing,6 mm space	2.90
double glazing,20 mm space	2.50
South severe, West, Southwest, Southeast, normal or Northwest, North, Nonheast, East sheltered:	
single glazing	5.00
double glazing,6 mm space	3.06
double glazing,20 mm space	2.67
West, Southwest, Southeast severe, Northwest, North,Northeast, East normal:	
single glazing	5.67
double glazing,8 mm space	3.29
double glazing,20 mm space	2.84
Exposure North-west severe:	
single glazing	6.47
double glazing,8 mm space	3.58
double glazing,20 mm space	3.00
Exposure North severe:	
single glazing	7.38
double glazing,6 mm space	3.80
double glazing,20 mm space	3.18

Source: Appendix 5.4 in (Koenigsberger, Ingaersoll, Mayhew, & Szokolay, 1973)

D. Conductance and resistance of cavities

Cavity		Conductance R_e W/m ² degC	Resistance 1/R _c m ² degC/W
Vertical: 3 mm wide		14.50	0.069
6 mm wide		8.74	0.114
13 mm wide		7.04	0.142
20 mm wide		6.63	0.151
25 mm wide		6.52	0.153
38 mm wide		6.52 -	0.153
Horizontal 76 mm:	Heat flow up	7.48	0.133
	Heat flow down	5.32	0.188
Values normally used in UK for:			
50 mm cavity		5.67	0.176
50 mm cavity, with aluminium foil		2.84	0.352
Appendix 5.6			
<i>Absorbance and emittance of surfaces</i>			
absorbance	<i>a</i> and <i>e</i>		
surface		for solar	
10 to 40			
radiation	<i>c</i>		
Black, non-metallic	0.85–0.98	0.90–0.98	
Red brick, stone, tile	0.65–0.80	0.85–0.95	
Yellow and buff brick, stone	0.50–0.70	0.85–0.95	
Cream brick, tile, plaster	0.30–0.50	0.40–0.60	
Window glass	Transparent	0.90–0.95	
Bright aluminium, gilt, bronze	0.30–0.50	0.40–0.60	
Dull brass, aluminium, galvanised steel	0.40–0.65	0.20–0.30	
Polished brass, copper	0.30–0.50	0.02–0.05	
Polished aluminium, chromium	0.10–0.40	0.02–0.04	

Appendix 6:

A. Embodied Energy in materials

Table A.1-10: Embodied energy in materials

	Embodied energy [MJ/kg]	[MJ/m ³]	[MJ/m ²]
Aggregate, general	0.1	150	\
virgin rock	0.04	63	\
river	0.02	36	\
Aluminium, virgin	191	515 700	\
extruded	201	542 700	\
extruded, anodised	227	612 900	\
extruded, factory painted	218	588 600	\
foil	204	550 800	\
sheet	199	537 300	\
Aluminium, recycled	8.1	21 870	\
extruded	17.3	46 710	\
extruded, anodised	42.9	115 830	\
extruded, factory painted	34.3	92 610	\
foil	20.1	54 270	\
sheet	14.8	39 960	\
Asphalt (paving)	3.4	7 140	\
Bitumen	44.1	45 420	\
Brass	62	519 560	\
Carpet	72.4	\	\
felt underlay	18.6	\	\
nylon	148	\	\
polyester	53.7	\	\
Polyethylene terephthalate (PET)	107	\	\
polypropylene	95.4	\	\
wool	106	\	\
Cement	7.8	15 210	\
cement mortar	2	3 200	\
fibre cement board	9.5	13 550	102/7.5mm
soil-cement	0.42	819	\
Ceramic			
brick	2.5	5 170	\
brick, glazed	7.2	14 760	\
pipe	6.3	\	\
tile	2.5	5 250	\
Concrete			
block	0.94	\	\
brick	0.97	\	\
GRC	7.6	14 820	\
paver	1.2	\	\
pre-cast	2.0	\	\
ready mix, 17.5 MPa	1	2 350	\
ready mix, 30 MPa	1.3	3 180	\
ready mix, 40 MPa	1.6	3 890	\
roofing tile	0.81	\	\
Copper	70.6	631 160	\
Earth, raw			
adobe block, straw stabilised	0.47	750	\
adobe, bitumen stabilised	0.29	\	\
adobe, cement stabilised	0.42	\	\
rammed soil cement	0.8	\	\
pressed block	0.42	\	\
Fabric			
cotton	143	\	\
polyester	53.7	\	\
Glass			
float	15.9	40 060	240/6mm
toughened	26.2	66 020	396/6mm
laminated	16.3	41 080	246/6mm
tinted	14.9	375 450	\
Insulation			
cellulose	3.3	112	\
fibreglass	30.3	970	\

polyester	53.7	430	\
polystyrene	117	2 340	\
wool (recycled)	14.6	139	\
Lead	35.1	398 030	\
Linoleum	116	150 930	337
Paint	90.4	118/l	6.5
solvent based	98.1	128/l	6.1
water based	88.5	115/l	7.4
Paper	36.4	33 670	\
building	25.5	\	4.97
kraft	12.6	\	\
recycled	23.4	\	\
wall	36.4	\	\
Plaster, gypsum	4.5	6 460	\
Plaster board	6.1	5 890	33/9.5mm
Plastics			
ABS	111	\	\
high density polyethylene (HDPE)	103	97 340	\
low density polyethylene (LDPE)	103	91 800	\
polyester	53.7	7 710	\
polypropylene	64	57 600	\
polystyrene, expanded	117	2 340	\
polyurethane	74	44 400	\
PVC	70	93 620	\
Rubber			
natural latex	67.5	62 100	\
synthetic	110	\	\
Sand	0.1	232	\
Sealants and adhesives			
phenol formaldehyde	87	\	\
urea formaldehyde	78.2	\	\
Steel, recycled	10.1	37 210	\
reinforcing, sections	8.9	\	\
wire rod	12.5	\	\
Steel, virgin, general	32	251 200	\
galvanised	34.8	273 180	\
imported, structure	35	274 570	\
Stone, dimension			
local	0.79	1 890	\
imported	6.8	1 890	\
Straw, baled	0.24	30.5	15.2
Timber, softwood			
air dried, rough sawn	0.3	165	\
kiln dried, roughs awn	1.6	880	\
air dried, dressed	1.16	638	\
kiln dried, dressed	2.5	1 380	\
mouldings, etc.	3.1	1 710	\
hardboard	24.2	13 310	\
MDF	11.9	8 330	\
glulam	4.6	2 530	\
particle bd	8	\	\
plywood	10.4	\	\
shingles	9	\	\
Timber, hardwood			
air dried, rough sawn	0.5	388	\
kiln dried, rough sawn	2	1 550	\
Vinyl flooring	79.1	105 990	\
Zinc	51	364 140	\
galvanising, per kg steel	2.8	\	\

B. Embodied Carbon in Building materials

The figures included in the following table are a much-shortened and abbreviated adaptation of a survey published by the Sustainable Energy Research Team (SERT) of the University of Bath. The survey, 'Inventory of Carbon & Energy (ICE)' V2.0, was compiled and written by Prof. Geoff Hammond & Craig Jones, in 2011. The full detailed survey, complete with original data, methodology and notes, is available at www.circularecology.com/ice-database.html. The figures are based on a 'Cradle-to-Gate' analysis of publicly available information.

Source: <https://www.greenspec.co.uk/building-design/embodied-energy/>

Material	Energy MJ/kg	Carbon kg CO ² /kg	Density kg /m ³
Aggregate	0.083	0.0048	2240
Concrete (1:1.5:3 eg in-situ floor slabs, structure)	1.11	0.159	2400
Concrete (eg in-situ floor slabs) with 25% PFA RC40	0.97	0.132	
Concrete (eg in-situ floor slabs) with 50% GGBS RC40	0.88	0.101	
Bricks (common)	3.0	0.24	1700
Concrete block (Medium density 10 N/mm ²)	0.67	0.073	1450
Aerated block	3.50	0.30	750
Rammed earth (no cement content)	0.45	0.023	1460
Limestone block	0.85		2180
Marble	2.00	0.116	2500
Cement mortar (1:3)	1.33	0.208	
Steel (general - average recycled content)	20.10	1.37	7800
Steel (section - average recycled content)	21.50	1.42	7800
Steel (pipe - average recycled content)	19.80	1.37	7800
Stainless steel	56.70	6.15	7850
Timber (general - excludes sequestration)	10.00	0.72	480 - 720
Glue laminated timber	12.00	0.87	
Sawn hardwood	10.40	0.86	700 - 800
Cellular glass insulation	27.00		
Cellulose insulation (loose fill)	0.94 – 3.3		43
Cork insulation	26.00*		160
Glass fibre insulation (glass wool)	28.00	1.35	12
Flax insulation	39.50	1.70	30*
Rockwool (slab)	16.80	1.05	24
Expanded Polystyrene insulation	88.60	2.55	15 – 30*
Polyurethane insulation (rigid foam)	101.50	3.48	30
Woodwool board insulation	20.00	0.98	
Wool (recycled) insulation	20.90		25*
Straw bale	0.91		100 – 110*
Mineral fibre roofing tile	37	2.70	1850*
Slate (UK – imported)	0.1 – 1.0	0.006 – 0.058	1600

Material	Energy MJ/kg	Carbon kg CO ² /kg	Density kg /m ³
Clay tile	6.50	0.45	1900
Aluminium (general & incl 33% recycled)	155	8.24	2700
Bitumen (general)	51	0.38 - 0.43	
Hardboard	16.00	1.05	600 - 1000
MDF	11.00	0.72	680 – 760*
OSB	15.00	0.96	640*
Plywood	15.00	1.07	540 - 700
Plasterboard	6.75	0.38	800
Gypsum plaster	1.80	0.12	1120
Glass	15.00	0.85	2500
PVC (general)	77.20	28.1	1380
PVC pipe	67.50	24.40	1400*
Linoleum	25.00	1.21	1200
Vinyl flooring	65.64	2.92	1200
Terrazzo tiles	1.40	0.12	1750*
Ceramic tiles	12.00	0.74	2000
Carpet tiles, nylon (Polyamide), pile weight 770g/m ²	279 MJ/m ²	13.7 / m ²	4.6 kg/m ²
Wool carpet	106.00	5.53	
Wallpaper	36.40	1.93	
Wood stain / varnish	50.00	5.35	
Vitrified clay pipe (DN 500)	7.90	0.52	
Iron (general)	25	1.91	7870
Copper (average incl. 37% recycled)	42	2.60	8600
Lead (incl 61% recycled)	25.21	1.57	11340
Ceramic sanitary ware	29.00	1.51	

Windows

1200 x 1200 2x glazed, air or argon filled	MJ per window	kg CO ²
Aluminium frame	5470	279
PVC frame	2150 - 2470	110 - 126
Aluminium clad timber frame	950 - 1460	48 - 75
Timber frame	230 - 490	12 - 25
Krypton filled add:	510	26
Xeon filled add:	4500	229

Paint

Material	Energy MJ/m ²	Carbon kg CO ² /m ²
Water-borne paint	59.0	2.12
Solvent-borne paint	97.0	3.13

Photovoltaic (PV) cells

Material	Energy MJ/m ²	Carbon kg CO ₂ /m ²
Monocrystalline (average)	4750	242
Polycrystalline (average)	4070	208
Thin film (average)	1305	67

Key: * - figures by *GreenSpec* obtained from publicly available information.

Appendix 7:

Criteria for selecting Building materials for construction

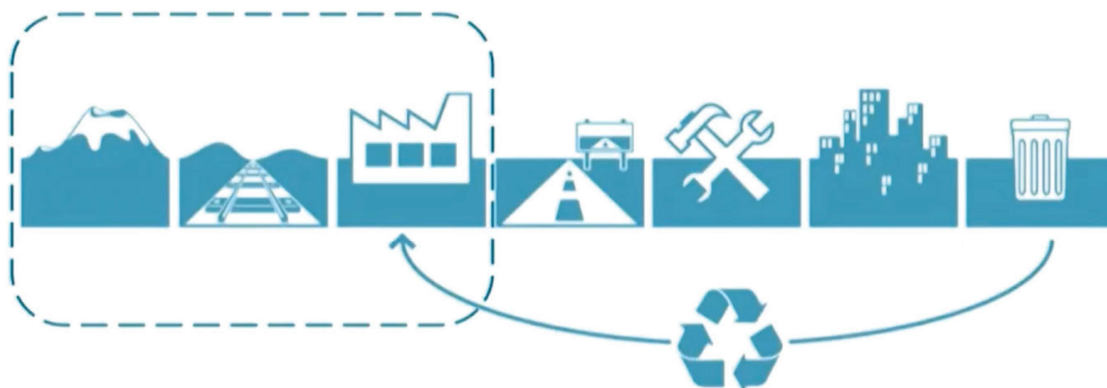
1.1.1 Embodied energy

The sum of energy that is consumed is often calculated from 'cradle to grave'. This includes:

1. Extraction of the raw material,
2. Transportation to factory,
3. Manufacture of product or components,
4. Assembly of product/system,
5. Transportation to site or point of sale,
6. Installation/construction,
7. Maintenance,
8. Replacement,
9. Disposal/re-purposing/recycling.

Besides, embodied energy is calculated for different scopes. To take the scope further wider, it can be extended from cradle to cradle. This mean, not only considering up to the disposal after demolition but further taking it into the manufacturing process for some other purposes. Cradle to gate, ie. From extraction to the consumer's construction site.

Figure 7: Cradle to cradle



1.1.2 Building Reuse

Building reuse is particularly applicable in the case of historic urban fabric and sites where some structures are already existing. This approach promotes extending the life cycle of existing building stock, conserving resources, retaining cultural resources, reducing waste and reducing environmental impacts of new buildings in terms of materials manufacturing and transportation. Using existing structural elements in at least 50% (by

area) of the completed building including additions should be the goal. Reusing existing buildings significantly reduces the energy use associated with the demolition process as well as construction waste. It also reduces environmental impacts associated with raw material extraction, manufacturing and transportation, water demand, pollution. It has economic benefits enormously saving cost. The existing structures can be reused in the following three ways:

1. **Reused area** – It refers to the total area of the building structure, core and envelope that existed in the prior condition and remains in the completed design.
2. **Retained components** – These are portions of the finished ceilings, finished floors, full-height walls and demountable partitions, interior doors, and built-in case goods that existed in the prior condition area and remain in the completed design.
3. **Adaptive reuse**– It is a renovation of a space for a purpose different from the original.

Step-by-step method for reusing structural and non-structural component of a building:

- Measure drawings detailed (walls, ceilings, doors, foundation, pavement) inventory
- Architectural design in order to retain as much as not compromising the functional requirement.
- Detailed exercise, need to plan well.
- Proper calculations need to be done to make visible the amount of material re-used.
- Re-use calculation by area.

Sample Building Structure and Envelope Re-use Calculation

Structure/Envelope Element	Existing Area (sf)	Re-used Area (sf)	Percentage Re-used (%)
Foundation/Slab on Grade	11,520	11,520	100
2nd Floor Deck	11,520	10,000	87
1st Floor Interior Structural Walls	240	240	100
2nd Floor Interior Structural Walls	136	136	100
Roof Deck	11,520	11,520	100
North Exterior Wall (excl. windows)	8,235	7,150	87
South Exterior Wall (excl. windows)	8,235	8,235	100
East Exterior Wall (excl. windows)	6,535	6,535	100
West Exterior Wall (excl. windows)	6,535	5,820	81
Total	64,476	61,156	95

Exclude the following items from this calculation: non-structural roofing material, window assemblies, structural and envelope materials deemed structurally unsound, hazardous materials, and materials that pose a contamination risk to building occupants.

- Maintaining the structural elements, intend to increase the use of non-structural elements
- Use existing interior non-structural elements (e.g., interior walls, doors, floor coverings and ceiling systems) in at least 50% (by area) of the completed building, including additions.
- Consider reusing existing building structures, envelopes and interior non-structural elements.
- Remove elements that pose a contamination risk to building occupants, and upgrade components that would improve energy and water efficiency such as mechanical systems and plumbing fixtures. Quantify the extent of building reuse.

- Confirm that the items designated for reuse can be reused and take the necessary steps to retain and maintain them in the finished work.
- Fixed items, such as non-structural walls and doors, are included in this credit and count toward the percentage of reuse when they perform the same function (e.g., doors reused as doors).

Method of calculation of the reused area:

- Take measurements as if preparing a bid for flooring, ceiling, or painting.
- Finished ceilings and flooring areas (tile, carpeting, etc.). Use square footage to determine area
- Interior non-structural walls. Determine the finished area between floor and ceiling and count both sides
- Exterior structural and party walls. If the interior finishes (e.g., drywall and plaster) have been reused, count only 1 side
- Interior doors. Count surface area once
- Interior casework. Calculate the visible surface area of the assembly; see the example in Figure 1
- The total area of all new and existing building materials is determined. The total area of only the existing and reused components is then entered. The sum of the existing material is then divided by the sum of the total building materials to obtain the overall percentage of retained components.
- Reuse of the material that is in good condition for structural and non-structure.

Sample Interior Nonstructural Reuse Calculation

Interior Non-Structural Element	Total Area (sf)	Existing/ Re-used (sf)	Percentage Reused (%)
Gypsum Board Wall Partitions - Full Height	5,400	3,600	67%
Gypsum Board Wall Partitions - Partial Height	650	650	100%
Carpeting	10,000	0	0%
Resilient Flooring	350	350	100%
Ceramic Tile	150	150	100%
Suspended Ceiling Systems	10,400	10,400	100%
Gypsum Board Ceilings	350	350	100%
Interior Doors (Wood)	525	420	80%
Interior Windows/Sidelights	56	56	100%
Interior Doors (Metal)	42	42	100%
Interior Casework/Cabinetry	235	150	64%
Totals	28,158	16,168	57%

Note: The Total Area calculation includes both new and existing/reused materials.

1.1.3 Material reuse

Reusing the material back into the building in some processed format. There are three types of material reuse:

- **Refurbished materials** are products that could have been disposed of as solid waste. These products have completed their life cycle as consumer items and are then refurbished for reuse without substantial alteration of their form. Refurbishing includes renovating, repairing, restoring, or generally improving the appearance, performance, quality, functionality, or value of a product.
- **Re-manufactured materials** are items that are processed into other products. One example is concrete that is crushed and used as sub-base.

- **Salvaged materials or reused materials** are construction materials recovered from existing buildings or construction sites and reused. Common salvaged materials include structural beams and posts, flooring, doors, cabinetry, brick, and decorative items. (e.g., broken bricks being used for paving) The sum of which constitutes at least 5%, based on cost, of the total value of the material on the project. Sometime salvaging may be more costly which environmental benefit still remains. Onsite material or Offsite reuse

Sample Salvaged Materials Tracking Log

Salvaged/Reused Material Description	Source for Salvaged/ Reused Material	Value / Product Cost (₹)
Salvaged Brick	ABC Salvage Suppliers	6,25,000
Salvaged Wood Floor	Salvage Company Y	2,42,000
Remanufactured Wood Doors (Used as Built-in Countertops)	On-Site Salvage / Remanufacture	42,000
Sub-Total Salvaged/Reused Materials		9,09,000
Total Construction Materials Cost - or 45% Default Materials Value		1,66,54,980
Salvaged/Reused Materials as a Percentage of Total Materials Cost		5.50%

Calculations

$$\text{Percentage of Reused Material} = \frac{\text{Cost of Reused Materials (NPR)}}{\text{Total Materials Cost (NPR)}} \times 100$$

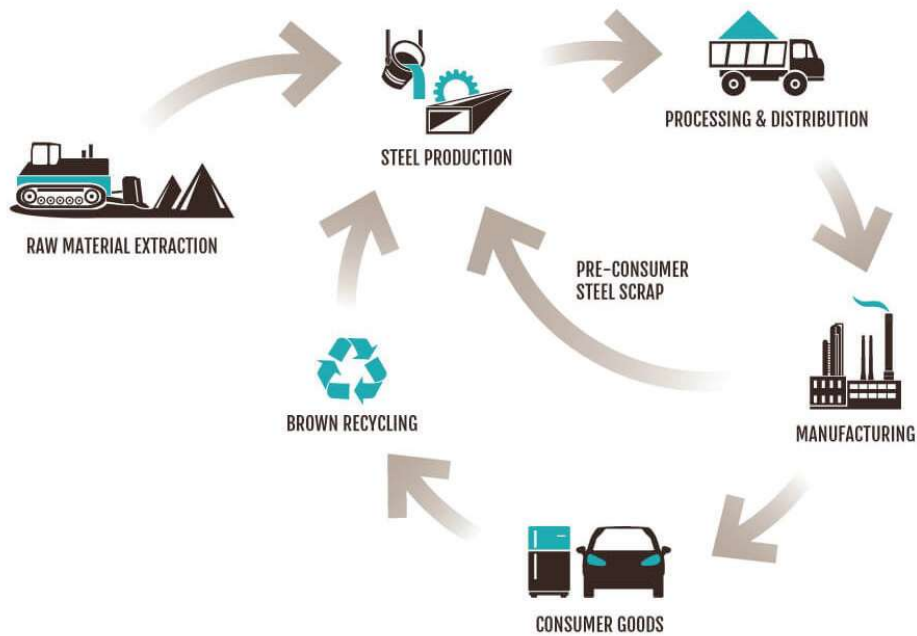
1.1.4 Recycled content

- Assembly recycled content is the percentage of material in a product that is either post-consumer or pre-consumer recycled content. It is determined by dividing the weight of the recycled content by the overall weight of the assembly.
 - Pre-consumer recycled content formerly known as post-industrial content is the percentage of the material in a product that is recycled from manufacturing waste. (e.g., Planer shavings, sawdust, bagasse, nut shells, culls, trimmed materials, and paper from over-used publications, obsolete inventories etc.) Excluded are rework, regrind, or scrap materials capable of being reclaimed within the same process that generated them. (ISO 14021)
- Recycled content is the proportion, by mass, of pre-consumer or post-consumer recycled material in a product (ISO 14021).
- Fly ash is the solid residue derived from incineration processes. Fly ash can be used as a substitute for Portland cement in concrete.



Pre-consumer versus post-consumer recycled content

STEEL RECYCLING & MANUFACTURE PROCESS



Some cases using recycled content may not give the same quality for durability as the new one.

Method of calculation for recycled content.

- Determine the total materials cost for the project by multiplying the total construction cost by 0.45.
- Alternatively, the total materials cost may be calculated based on the actual materials costs from the project schedule of values or a similar document.
- The benefit of using actual materials costs, as opposed to the default 45%, is that projects with less than 45% materials cost can more easily achieve the 10% and 20% credit thresholds.
- Materials costs include all expenses to deliver the material to the project site.

Equation 1

$$\text{Recycled Content Value(NPR)} = \frac{(\% \text{ Post-consumer Recycled Content } \times \text{Materials Cost})}{(\% \text{ Pre-consumer Recycled Content } \times \text{Materials Cost})} + 0.5$$

Equation 2

$$\text{Percentage Recycled Content} = \frac{(\text{Total Recycled Content Value})}{(\text{Total Materials Cost})} \times 100$$

Calculate the project’s percentage recycled content according to Equation 2.

Assembly recycled content

An assembly can be either a product formulated from multiple materials (e.g. a composite wood panel) or a product made up of a sub-component (e.g. a window system). For assembly recycled content value, determine the percentage by weight of the post-consumer recycled content and the pre-consumer recycled content.

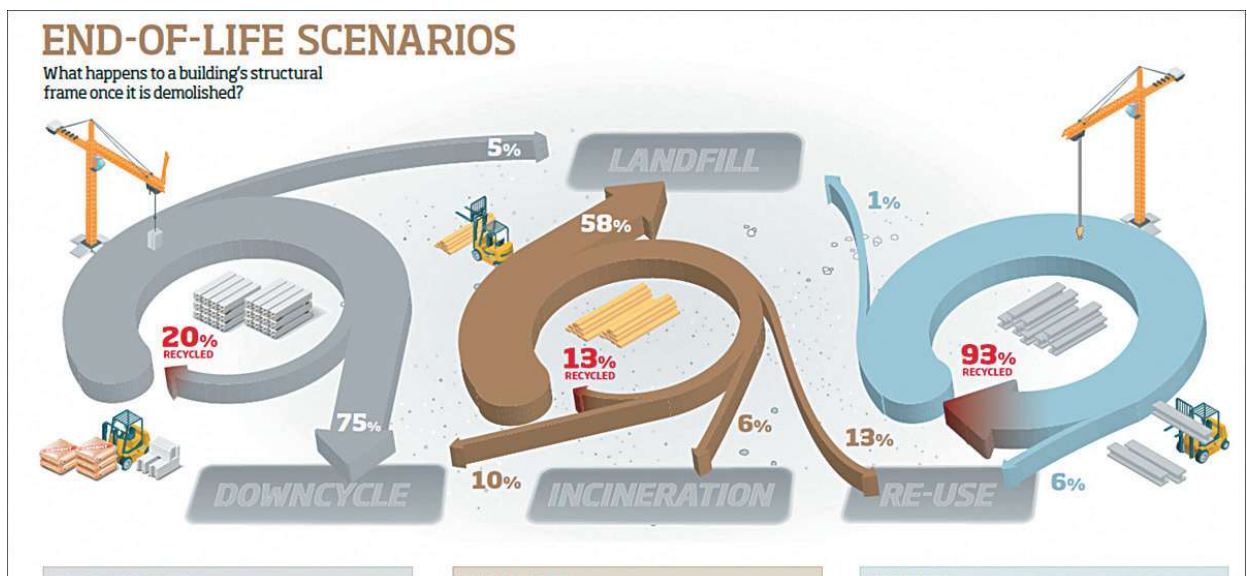
Equation 3

$$\text{Assembly recycled content value (NPR)} = \frac{\% \text{ Post consumer recycled content}}{\text{Total assembly weight}} \times \text{Assembly cost} + \frac{\% \text{ Pre-consumer recycled content}}{\text{Total assembly weight}} \times 0.5 \times \text{Assembly cost}$$

Sample calculation for the recycled content:

Total construction cost						60,00,000.00
Default Total material cost (45% of Total Construction Cost)						27,00,000.00
Product Name	Vendor	Product Cost	% Post-consumer	% Pre-consumer	Recycled Content Value (Equation 1)	Recycled Content Information Source
Structural steel	Multi Steel	4,00,000	10.00%	85.00%	2,10,000	Structural manufacturer
Underlay aggregate	ABC Foundation	2,10,000	20.00%		42,000	Concrete manufacturer
Particleboard	Sol's Big Boards	40,000		100.00%	20,000	Manufacturer
Gypsum board	Gypsum R Us	85,500		78.00%	33,350	Manufacturer
Combined value of post-consumer + 1/2 pre-consumer content (Total recycled content value)						3,05,350
Combined value of post-consumer + 1/2 pre-consumer content, as a percentage of default total materials cost (Total percent recycled content) (Equation 2)						11.31%
Total points documented						1

Steel is 100% recyclable and its energy intensity decreases with each recycling, similar to aluminium. For steel products where recycled content information is unavailable, assume the recycled content to be 25% post-consumer. No other material is recognized to have such a consistent minimum recycled content. Many steel products contain 90% or higher recycled content if manufactured by the electric arc furnace process, so it may be beneficial to obtain actual information from the manufacturer rather than relying on the default value.



It is a good example for Cradle to cradle life cycle. Wood is generally more suited for cradle to grave cycle. Concrete, on the other hand, is not commonly recycled to the same extent. Hence, steel is an excellent choice for the tall buildings.

1.1.5 Local material

Extracted and manufactured within the region, where the region is defined as a 400km radius. Transportation, the use of conventional fuels, and the associated economic and social benefits such as skill development and support are important factors. The process include:

- Establish a project goal for locally sourced materials, and identify materials and material suppliers that can achieve this goal.
- During construction, ensure that the specified local materials are installed, and quantify the total percentage of local materials installed.
- Consider a range of environmental, economic and performance attributes when selecting products and materials.
- Run preliminary calculations, as soon as a project budget is available, to set appropriate regional materials targets.
- Architects should specify in the construction documents products that are extracted/harvested/recovered and manufactured within 400 km and work with the general contractor on approved alternatives.
- Use building materials or products that have been extracted, harvested or recovered, as well as manufactured, within 250 miles (400 km) of the project site for a minimum of 10% or 20%, based on cost, of the total materials value. If only a fraction of a product or material is extracted, harvested, or recovered and manufactured locally, then only that percentage (by weight) must contribute to the regional value.

Sample Assembly Percentage Regionally Extracted Calculation for Concrete

$$\text{Percentage of Local Materials} = \frac{\text{Total Cost of Local Materials (₹)}}{\text{Total Materials Cost (₹)}} \times 100$$

Components	Weight (kg)	Distance between Project & Extraction Site (km)	Weight Contributing to Regional Extraction (kg)
Cement	282	1,250	0
Fly Ash	282	125	282
Water	275	1	275
Slag	750	370	750
Recycled Concrete & Aggregate	1,000	8	1,000
Sand	1,200	18	1,200
Component Totals	3,789	NA	3,507
Percent Regionally Extracted Materials (3,507/3,789)			92.6%

Sample Spreadsheet for Regional Materials

Product	Manufacturer	Distance between Project & Manufacturer (km)	Distance between Project & Extraction/harvest (km)	Product Cost (NPR)	Value Qualifying as Regional (NPR)	Information Source
Plant Material	Green's Landscape	5	5	67,700	67,700	Contractor submittal
Concrete	Joe's Concrete	15	15	2,10,000	2,10,000	Contractor submittal
Insulation	UR Warm	105	1,080	92,500	-	Product cut sheet
Gypsum	Gypsum R Us	75	288	85,500	85,500	Letter from manufacturer
Carpet	Fiber Good	355	721	1,53,330	-	Letter from manufacturer
Casework	Top Counter	18	320	1,22,000	1,22,000	Contractor submittal
Lumber	My Mill	110	320	3,89,900	3,89,900	Contractor submittal
Wood Doors	Closeby	71	320	70,000	70,000	Contractor submittal
Total Cost of Regional materials						94,510
Total Materials Cost (Divisions 2-10)						7,51,000
Percentage of Regional Materials						13%
Points Earned						1

This can also be calculated using the cost of the material.

The total construction cost for a library building is Rs 6000000. Using the default material calculations, the total cost of materials excluding labor and equipment is $6000000 \times 0.45 = \text{Rs } 2700000$.

The table lists the regional materials purchased for the project. In this example, the cost of regionally harvested and manufactured products as a percentage of the total cost of material is 27.89%.

Total construction cost						60,00,000
For Default total materials cost						60,00,000
Provide total materials cost (exclude labor, equipment)						27,00,000
Product Name	Vendor	Product Cost (NPR)	Distance between project and manufacturer (km)	Distance between project and extraction site (km)	Regional content information source	
Plant material	Green Landscaping	67,700	40	8	Manufacturer	
Concrete aggregate	Joe's Concrete	2,10,000	8	24	Concrete manufacturer	
Gypsum board	Gypsum R Us	85,500	120	363	Manufacturer	
Wood flooring	Lumber Specialists	3,89,900	192	260	Mill	
The combined value of post-consumer and half of pre-consumer content						3,05,350
Total cost of locally manufactured and extracted materials						7,53,100
Cost of regionally manufactured products as a percentage of the cost of all materials						27.89%

1.1.6 Rapidly Renewable Material

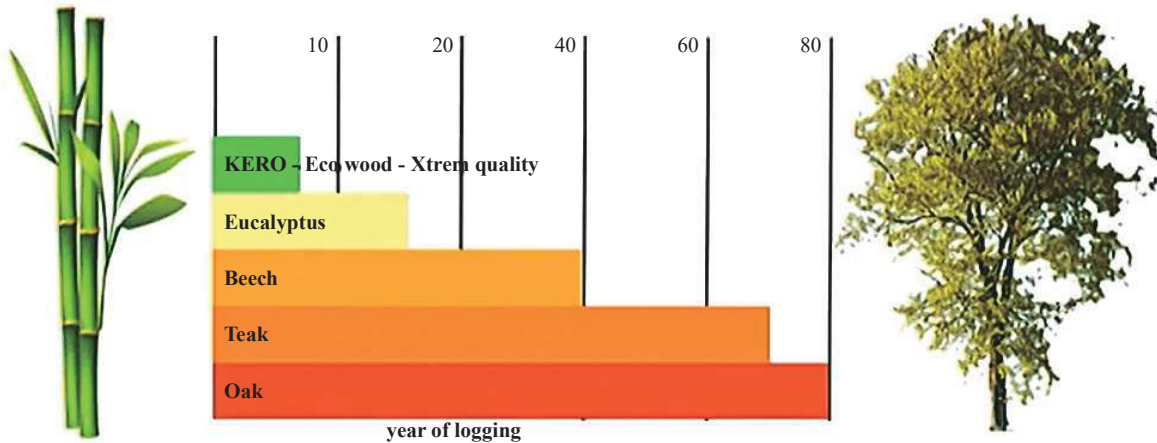
Rapidly renewable building materials and products are made from agricultural product that are typically harvested within a 10 years or shorter cycle. That includes bio-based products made from plant harvested on a 10-year (or shorter) cycle. The goal of using rapidly renewable content is to reduce the number and quantity of products made from fossil fuel derivatives. Timber 20 year and plus so this does not come under this criterial.

- Bamboo flooring, plywood,
- Cotton batt insulation
- Sunflower seed board panels
- Wheat board cabinetry
- Wool carpeting
- Cork fooling
- Bio-based paints
- Geo-textile fabrics such as coir or jute
- Straw bales

The use of rapidly renewable materials offers several advantages including reduced land consumption, social and economic benefits, and positive environmental impacts.

Some of these materials are agricultural by-products and contribute to sustainable resource management. They also help conserve water resources. The goal is to minimize the use and depletion of finite raw materials and long cycle renewable resources by replacing them with rapidly renewable alternatives.

Use rapidly renewable building materials and product for 2.5% of the total value of all building materials and products used in the project, based on cost.



Example:

- The Total construction cost for a school building is 60,00,000. Using the default materials calculations, the total cost of materials (excluding labor and equipment) is 60,00,000 x 0.45 = 27,00,000.
- In this example, the total percentage of rapidly renewable content to total cost of all materials is 4.86%

Sample Calculations for Rapidly Renewable Material

Total Construction cost for default total materials cost; OR					₹ 60,00,000
Provide total materials cost (exclude labor, equipment)					₹ 27,00,000
Product Name	Vendor Name	Assembly Product Cost (NPR)	% Rapidly Renewable Content (if part of an assembly)	Value of Rapidly Renewable Content (NPR)	Recycled content information source
Countertop wheatboard	Rho Company	67,000	30.00%	20,100.00	Vendor
Linoleum flooring	Tau Floors	8,820	50.00%	4,410.00	Manufacturer letter
Bamboo window blinds	Upsilon Shades	1,40,790	75.00%	1,05,590.25	Website
Totals		2,16,610		1,30,100.25	
Value of rapidly renewable content					1,30,100
Percentage cost of rapidly renewable content total cost of all materials					4.86%
Points documented					1

Specific operation and maintenance requirements must be identified, understood, and properly implemented. For the materials such as Bamboo or cork flooring, moisture should be prevented and damp mopping should be carefully managed. Proper training should be provided to ensure that specified practices are followed consistently.

1.1.7 Certified Wood

Wood is a renewable material but it may not always qualify as a rapidly renewable resource. However, it can still be used sustainably if sourced from well-managed forests.

Chain-of-custody (COC) is a tracking procedure for a product from the point of harvest or extraction to its end use, including all successive stages of processing, transformation, manufacturing, and distribution.

Chain-of-custody certification is awarded to companies that produce, sell, promote, or trade forest products after audits verify proper accounting of material flows and proper use of the Forest Stewardship Council name and logo. The COC certificate number is listed on invoices for non-labelled products to document that an entity has followed FSC guidelines for product accounting.

Sustainable forestry is the practice of managing forest resources to meet humans' long-term forest product needs while maintaining the biodiversity of forested landscapes. The primary goal is to restore, enhance, and sustain a full range of forest values, including economic, social, and ecological considerations.

A vendor of certified wood is a company that supplies wood products to contractors or subcontractors for on-site installation. A vendor needs a chain-of-custody number if it is selling FSC-certified products that are not individually labelled; this includes most lumber.

At least 50% of the wood products should be FSC-certified. This can include wood sourced from community forests, sustainable forestry practices, FSC-certified wood imports from a foreign countries. Moreover, minimizing or eliminating the use of wood products can also support sustainability. Certification by forest officers ensure responsible sourcing and environmental stewardship.

1.1.8 Pollutant-free materials

The building materials should be environment-friendly and free of pollutants. The following materials should be avoided if the value of the content exceeds its permissible limit.

- **CFCs and HCFCs:** Chlorofluorocarbons, which are ozone-depleting chemicals used in mechanical equipment, should be avoided.
- **VOCs** – Volatile Organic Compounds found in paints and coatings, adhesives and sealants, carpets and composite wood.
- **PVC**
- **CCA** – Wood treated with copper chromium arsenate
- **PBT** – Persistent, Bio accumulative Toxic Chemicals e.g. mercury, lead, cadmium. These can be found in paints, varnishes, caulks, electrical switches and thermostats, fluorescent bulbs, solders and vinyl.

Appendix 8

A. Water Supply Requirements for Buildings (NBC 208 : 2003)

	Type Buildings	Requirement per
1	Apartment Buildings	100 lit
2	Auditorium (per seat)	15 lit
3	Hospitals (including laundry) per bed	
	a) Number of beds <100	340 lit
	b) Number of beds >100	450 lit
4	Cold Storage	45 lit
5	Buildings Higher than 4-Storey Commercial & Industrial)	45 lit
6	Residences	100 lit
7	Office	45 lit
8	Hostels (including quarters for nurses etc.)	100 lit
9	Hotels (per bed)	100 lit
10	Restaurants (per seat)	50 lit
11	Schools and colleges	
	a) Day schools	15 lit
	b) Boarding schools	100 lit
12	Cinemas, Theatre Halls. Concert hall (per seat)	15 lit
13	Factories	
	a) With bathing facilities	45 lit
	b) Without bathing facilities	30 lit
14	Terminal stations (Bus and Railways)	15 lit
15	Airports (International)	70 lit
16	Airports (Domestic)	20 lit

B. Typical coefficient of run-off figures (NBC 208 : 2003)

	Surface Type	Coefficient of Run-off
a)	Terrace, Hard paved surface:	0.90-0.95
b)	Paved surface, roads:	0.85-0.90
c)	Gravel paths, loosely paved walks, rocky surface	0.70-0.85
d)	Brick paved, compacted ground, turf:	0.50-0.70
e)	General ground	0.50-0.60
f)	Natural ground, sloping ground:	0.20-0.50

C. Nepal's Drinking Water Quality Standards

Group	Parameter	Unit	Maximum Concentration Limits
Physical and chemicals	Turbidity	NTU	5 (10)**
	pH		6.5-8.5*
	Color	TCU	5 (15)**
	Taste & Odor		Would not be objectionable
	Total Dissolved Solids	mg/l	1000
	Electrical Conductivity	µc/cm	1500
	Iron	mg/l	0.3 (3)**
	Manganese	mg/l	0.2
	Arsenic	mg/l	0.05
	Cadmium	mg/l	0.003
	Chromium	mg/l	0.05
	Cyanide	mg/l	0.07
	Fluoride	mg/l	0.5-1.5*
	Lead	mg/l	0.01
	Ammonia	mg/l	1.5
	Chloride	mg/l	250
	Sulphate	mg/l	250
	Nitrate	mg/l	50
	Copper	mg/l	1
	Total Hardness	mg/l	500
Calcium	mg/l	200	
Zinc	mg/l	3	
Mercury	mg/l	0.001	
Aluminum	mg/l	0.2	
Residual Chlorine	mg/l	0.1-0.2*	
Micro Germs	E-Coli	MPN/100ml	0
	Total Coli form	MPN/100ml	95 % in sample

Note: * These standards indicate the maximum and minimum limits.

** Figures in parenthesis are upper range of the standards recommended.

Source: Environment Statistics of Nepal 2008, Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics, Kathmandu, Nepal

D. Wastewater Effluent Standard

Parameter	Unit	Concentration not to Exceed	Analysis Method
pH	Standards unit	6.0 – 9.0	4500 HB, APHA* 22 nd edition
Total Suspended Solid (TSS)	mg/l	60	2440 D, APHA 22 nd edition
Biological Oxygen Demand (BOD)	mg/l	50	5210 B, APHA 22 nd edition
Chemical Oxygen Demand (COD)	mg/l	Monitor and report only	5220, APHA 22 nd edition
E. Coli	CFU/100 ml	1000	9222, APHA 22 nd edition

*APHA: American Public Health Association

Appendix 9

Sample calculation for rainwater storage tank

Case I - When rainwater collection is more than the dry period demand:

Provided,

Rainfall (P) = 1650 mm

Catchment area (A) = 100 sqm

Run off coefficient (C) = 80%

Total rainwater collection = P x A x C = 1650 x 100 x 0.8 = 1,32,000 liters

Let,

The longest dry period = 90 days (considering absolute dry month is 3)

Water demand = 80 lpcd

Nos. of family member = 5

Dry period demand = 90 x 5 x 80 = 36,000 liters

Thus, Total rainwater collection > Dry period demand

So, Volume of storage tank = 36,000 ltrs

Case II - When dry period demand is more than rainwater collection:

Provided

Rainfall (P) = 500 mm

Catchment area (A) = 100 sqm

Run off coefficient (C) = 80%

Total rainwater collection = P x A x C = 500 x 100 x 0.8 = 40,000 ltrs

Let,

The longest dry period = 120 days (considering absolute dry month is 4)

Water demand = 80 lpcd

No of family member = 5

Dry period demand = 120 x 5 x 80 = 48,000 liters

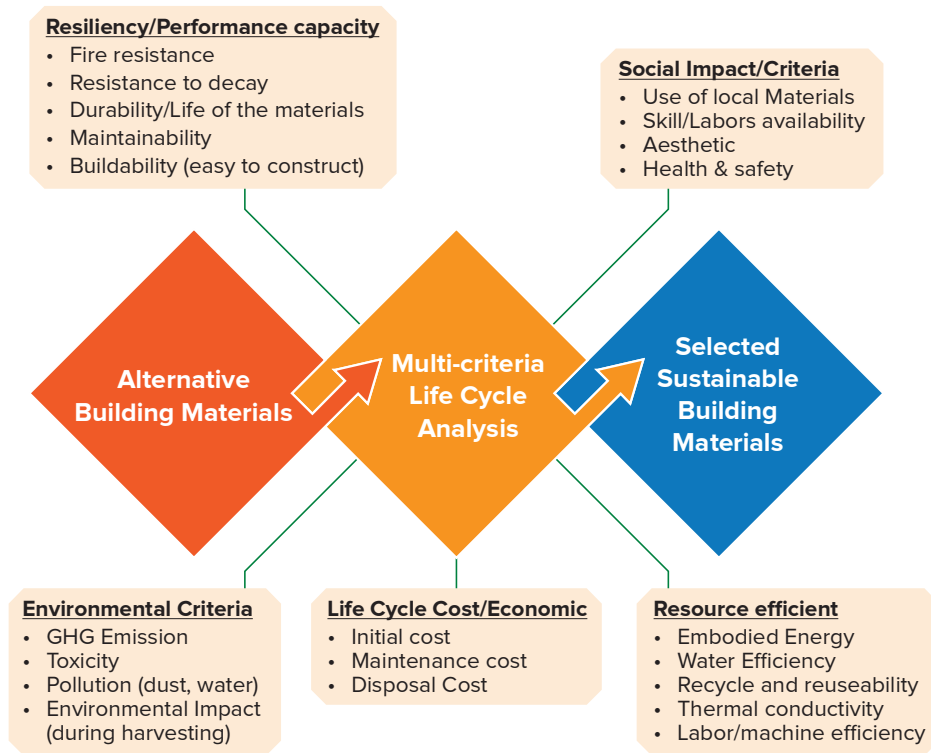
Thus, Dry period demand > Total rainwater collection

So, Volume of storage tank = 40,000 ltrs

Appendix 10

Multicriteria life cycle analysis

Figure: Multicriteria Life cycle analysis



Multi-criteria decision-making tool for selection of SBM

S.No.	Criteria and Indicators	Score				
		1	2	3	4	5
1 Environmental Criteria						
1.1	GHG emission					
1.2	Environmental Impact during harvest					
1.3	Potential for recycle and reuse					
1.4	Environmentally sound disposal options					
1.5	Zero or low toxicity					
1.6	Minimum Pollution (air, water, land etc)					
2 Technical Criteria						
2.1	Life expectation of materials (Strength & Durability)					
2.2	Fire resistance					
2.3	Resistance to delay					
2.4	Maintainability					
2.5	Thermal Insulation					

3 Resource Consumption Criteria					
3.1	Embodied Energy				
3.2	Material availability locally				
3.4	Water efficiency				
3.5	Amount of likely wastage in use				
3.6	Amount of transportation required				
4 Socio-economic Criteria					
4.1	Life cycle cost (initial, maintenance/repair & disposal cost)				
4.2	Buildability (Ease of construction)				
4.3	Use of local materials and technologies				
4.4	Aesthetic/Social acceptability				
4.5	Health & safety				
5 Legal Criteria					
5.1	Availability of codes, standard, guideline				
5.2	Building Permit				
5.3	Financial Provision (loan from Financial Institutions)				
5.4	Incentive				

Appendix 11

VOC limit of different materials

Application / Product Type	Maximum VOC Limit (g/L less water)
Flat paint	50
Non-flat paint	150
Anti-rust paint	250
Lacquer (clear wood finish)	550
Sanding Sealer (clear wood finish)	350
Varnish (clear wood finish)	350
Floor coating	100
Shellac (clear)	730
Shellac (pigmented)	550
Stain	250
Faux Finish Coating	350
Architectural sealant	250
Non-membrane roof sealant	300
Single ply roof membrane	450
Waterproofing sealer	250
Waterproofing sealer (concrete/masonry)	400
All other sealers	200
Indoor adhesive	50
Wood flooring adhesive	100
Subfloor adhesive	50
Ceramic tile adhesive	65
Contact adhesive	80
Drywall panel adhesive	50
Multipurpose construction adhesive	70
Structural glazing adhesive	100
Special purpose contact adhesive	250
PVC welding	510
Concrete curing compound	350
Wood preservative	350

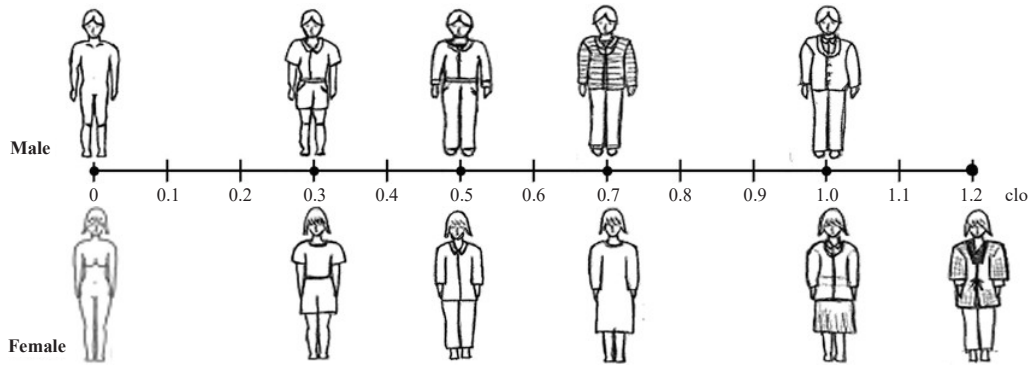
VOC Levels are measured in grams of VoC per liter of material.

Source: USGBC LEED Addenda #100000419, 14 April 2010

Glossary

Clothing (Clo) Value - Clo value is a measure of the thermal resistance of clothing, and it is an important factor in determining thermal comfort. Our clothes interfere with our ability to lose heat. A resistance of 0.155 m².K/W is considered a 1 Clo.

Figure 8 : The change in Clo Value based on the clothing type providing thermal resistance.



Dry Bulb temperature (DBT) or Air temperature - The DBT is the temperature of air measured by a thermometer freely exposed to the air but shielded from radiation. DBT is the temperature that is usually thought of as air temperature and does not indicate the amount of moisture in the air. It is usually expressed in °C.

Metabolic rates (MET)

The amount of heat that human body releases is the metabolic rate. This depends on the activities they are doing. An average person seated at rest generally produces 60 W/m². This is generally termed as 1 met. The more strenuous the activity, the more heat is produced.

Activity of a human body is directly related to the Thermal Comfort, as different levels of activities produce different level of heat from a body. A certain level of activity can help to achieve comfort during winter, but the same level of activity can be discomfortable during summer.

Figure 9 : Metabolic rates (met Rate) for different activities.



(Source: ASHRAE, 2010)

How fast your body burns energy depends on how active you are. This energy use is called your metabolic rate. The amount of energy you burn can be measured in units called 'mets.' One met is equal to 58.2 watts per square meter of your body's surface area.

The body surface area can be measured as:

$$A_D = 0.202 \times M^{0.425} \times h^{0.725}$$

Where,

M= Mass of the body

h = height

(Du Bios & Du Bois, 1916)

For a person who weighs 80 kilograms and is 1.8 meters tall, the normal metabolic rate is about 115 watts. If this person becomes more active, his/her metabolic rate will increase.

Globe Temperature – The temperature measured by globe thermometer as a means of assessing the combined effects of radiation, air temperature and air velocity on human comfort. It consists of a hollow copper sphere painted matt black to absorb radiant heat, with a temperature sensor at its center. When it reaches a steady state (after 15 minutes or so depending on the size of the globe and the environmental conditions), the heat exchanges through convection and radiation will be in equilibrium, and the temperature recorded by the sensor will be somewhere between the air and radiant temperature. This is referred to as the globe temperature (t_g) or black globe temperature and resembles the thermal conditions felt by the human body. The standard sphere has a diameter of 150 mm. Smaller sizes are available but they increase the influence of convection on the recorded temperature.

Green Building: A green building, also known as a sustainable or eco-friendly building, is a structure that is designed, constructed, and operated with a focus on minimizing its environmental impact throughout its entire lifecycle, while promoting occupants' health and well-being. Green building practices aim to use resources more efficiently, reduce waste, conserve energy and water, and create healthier and more comfortable indoor environments.

Air speed / Air movement - It is the average speed of air that indicates how fast/slow the air is moving in a space. It is usually expressed in terms of m/s. Since the speed of air changes constantly, it is averaged over time intervals between one to three minutes.

clo - A unit used to express the thermal insulation provided by garments and clothing ensembles; 1 clo = 0.155 m²·°C/W (0.88 ft²·h·°F/Btu).

Mean radiant Temperature (MRT) - MRT is a measure of average temperature of all surfaces surrounding us, with which the human body exchanges thermal radiation. It signifies the radiant heat from all the surfaces that surround a point / person in space, including walls, floors, and ceilings. As radiation is the dominant form of heat transfer from the human body, MRT is an important factor in thermal comfort because it influences the amount of heat radiated from the surrounding surfaces to the body, and vice versa. ASHRAE Standard 55, 2010 defines it as “The uniform surface temperature of an imaginary black enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform space”. $MRT = T_g + 2.42 \times V (T_g - T_a)$

Where,

T_g = Globe Temperature

V = Air velocity in centimeter per second

T_a = Air Temperature

MRT can be used to calculate the Operative Temperature.

$$T_o = 0.5 T_{dbt} + 0.5 T_{mrt}$$

Where, T_o = Operative Temperature

T_{dbt} = Dry Bulb Temperature

T_{mrt} = Mean Radiant Temperature

Operative temperature - Operative temperature is one of the simplified measures of human thermal comfort derived from air temperature, mean radiant temperature and air speed. The building design should aim to achieve a comfortable operative temperature which is defined as the weighted average of the mean radiant and ambient air temperatures based on their respective heat transfer coefficients. (ASHRAE, Handbook on Fundamentals, 2009)

$$t_o = At_a + (1 - A) t_{mtr}$$

Where,

t_o = operative temperature

t_a = average air temperature

t_{mtr} = mean radiant temperature

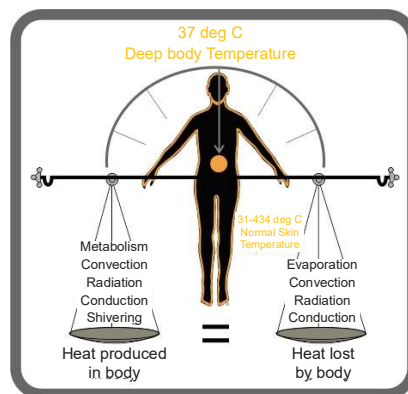
A can be selected from the following values as a function of the average air speed V_a .

V_a	<0.2 m/s (<40 fpm)	0.2 to 0.6 m/s (40 to 120 fpm)	0.6 to 1.0 m/s (120 to 200 fpm)
A	0.5	0.6	0.7

Heat Balance Model - The heat balance method presents a physics based mathematical model that establishes thermal comfort when heat loss from the body is exactly equal to heat produced within the body. The heat balance method approaches thermal comfort from a biological perspective.

- If heat generation rate > heat loss rate, individual will feel warm/ hot
- If heat generation rate < heat loss rate, individual will feel cool/ cold
- For thermal comfort, heat generation rate = heat loss rate

Figure 10 : Heat Balance model (NZEB, 2024)



The acceptable thermal comfort range in the heat balance method is defined by PMV and PPD.

PMV & PPD - The Predicted Mean Vote (PMV) is an index that predicts the mean value of the votes of a large group of persons on the 7-point thermal sensation scale, based on the heat balance of the human body. The sensation scale is expressed from -3 to +3 corresponding to the categories “cold,” “cool,” “slightly cool,” “neutral,” “slightly warm,” “warm,” and “hot.” Thermal balance is obtained when the internal heat production in the body is equal to the loss of heat to the environment. PMV may be calculated for different combinations

of metabolic rate, clothing insulation, air temperature, mean radiant temperature, air velocity and air humidity (ISO:7730, 2005). Once the PMV is calculated, the PPD or Predicted Percentage of Dissatisfied, can be determined. PPD is an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people who feel too cool or too warm. Thermally dissatisfied people are those who vote hot, warm, cool or cold on the 7-point thermal sensation scale.

The heat balance method provides quantification of the heat exchange between human body and immediate surrounding environment. It is based on the thought that perception of thermal comfort in occupant depends only on human physiology and heat transfer mechanisms between the environment and body. However, research has shown that thermal comfort perception is also influenced by social factors and the occupants' psychological responses to the environment.

Adaptive Thermal Comfort Model - Human beings naturally adjust and adapt to the outdoor weather conditions to reduce discomfort through adjustments, like altering activity, posture, clothing, and opening or closing windows. Additionally, their comfort range indoors varies depending on the prevailing outdoor temperature conditions.

The adaptive thermal comfort model was developed to account for behavioral and psychological adaptations of the human body. It considers physiological, psychological, and behavioral factors that influence occupants; perception of thermal comfort.

ASHRAE 55 uses an adaptive comfort model to recommend acceptable thermal conditions for naturally ventilated spaces.

Strategic landscaping – It refers to the deliberate planning and design of outdoor spaces to achieve specific goals or objectives. It considers aesthetics, functionality, sustainability, and budget constraints to create a cohesive and purposeful outdoor environment. This approach may encompass elements such as the selection and arrangement of plants, trees, and other greenery, as well as the integration of hardscape features like paths, patios, and water features.

Box 1 : Web Sources for getting Sun ath diagram

<https://clima.cbe.berkeley.edu/>

<https://www.suncalc.org/>

<https://drajmarsh.bitbucket.io/sunpath3d.html>

<https://drajmarsh.bitbucket.io/sunpath2d.html>

https://www.sunearthtools.com/dp/tools/pos_sun.php?lang=en

<https://www.jaloxa.eu/resources/daylighting/sunpath.shtml>

अनुसूची ३: मार्गदर्शन (Signage) प्रयोगको मापदण्ड

(Guidelines for Signage Use in Government Office Buildings)



Government of Nepal
Ministry of Infrastructure Development
Singhadurbar, Kathmandu, Nepal

Physical Infrastructure and Standardized Layout of Government Offices-2083

ANNEX-III

Guidelines for Signage Use in Government Office Buildings

1. CLASSIFICATION OF SIGNAGE ON BASIS OF USAGE

The signage in buildings can be classified on the basis of usage as

1. Safety Signage
2. Identification and Wayfinding Signage
3. Permanent Rooms and Spaces Signage
4. Tactile Signage
5. Braille Signage
6. Core Building Signage
7. Instruction and Prohibition Signage
8. Location at Doors

1.1 Safety Signage

Safety Signage shall be provided and maintained in circumstances where a health and safety risk or hazards are identified.

Mandatory safety signage consists of:

1. Warning Signage
2. Prohibition Signage
3. Mandatory Action Signage
4. Emergency Signage
5. Fire Safety Signage (Information for Fire Emergency)

1.1.1 Warning Signage

- Warn of a hazard or danger, such as “Danger: Toxic materials”.
- Triangular shape, and usually feature a black pictogram with black edging (the yellow part to take up at least 50% of the area of the signage).



Figure 1-1 Warning Signs

1.1.2 Prohibition Signage

- Prohibit action which is likely to increase or cause danger, such as “No entry”.
- Round shape with black pictogram on white background and either red edgings or a diagonal line (the red part to take up at least 35% of the area of the signage).



Figure 1-2 Prohibitory Signage

1.1.3 Mandatory Action Signage

- Prescribes specific behavior such as “Eye protection must be worn”.
- Round shape with white pictogram and blue background (the blue part to take up at least 50% of the area of the signage).



Figure 1-3 Mandatory Signage

1.1.4 Emergency Signage

- Information for emergency situations-

- Rectangular or square shape with white pictogram and green background.



Figure 1-4 Emergency Escape Signage

1.1.5 Fire Safety Signage (Information for Fire Emergency)

- Combination of warning and emergency signage
- Information in escape routes and emergency exit (colored green)
- Information on the identification or location of firefighting equipment (colored red)
- Fire exit signage shall be displayed immediately above or near to the exit opening, where it least likely to be obscured or obstructed by smoke.
- Buildings that have multiple occupants shall adopt a common approach to the provision of fire safety signage, to avoid confusion about exit routes.



Figure 1-5 Fire-Safety Signage

1.2 Identification and Wayfinding Signage

Signage shall be used externally to identify a building by its street number or name. Internally, signage shall be used to identify rooms or areas by name, number, or function.

Wayfinding signage shall provide direction to a particular room or area and is important in large, complex buildings such as hospitals, educational facilities or transport terminals.



Figure 1-6 Identification and Wayfinding Signage

1.2.1 Universal Messaging

A uniform style is considered desirable for wayfinding consistency and clarity. Standardized colors, fonts, icons and signage shapes can also improve universal recognition.

The following colors are generally associated with specific basic responses:

- Green for safety
- Red for emergency
- Yellow for caution

These three colors are easily identified by most people, regardless of age and other demographic factors, but other colors are also commonly used to represent different common messages.

1.2.2 Forms of Wayfinding

In multi-story buildings, flooring and wall coverings shall be color coded for quick recognition. This technique shall be frequently used in large car parks, hospitals and care homes (particularly in those where residents may be living with vision or memory impairments). While color coded finishes shall not replace traditional wayfinding methods, such as directional arrows, pictograms or clearly worded signage and numbered floors, it can enhance it.

Lighting shall also be used as a form of wayfinding, particularly in long corridors. Emergency exit lighting illustrates how wayfinding shall be used to guide people to their destination.

Textures (particularly in floor coverings), ambient sounds (such as music) and even smells (such as those associated with kitchen or restaurants) shall also inform wayfinding decisions.

1.2.3 Elements of Effective Wayfinding

Characteristics that might contribute to successful wayfinding include:

- Simplicity
- Color
- Clarity
- Size
- Placement
- Inclusivity
- Hierarchy
- Consistency

1.3 Permanent Rooms and Spaces Signage

Signage that identifies permanent rooms and spaces include:

- Room and floor numbers or letters;
- Room names; and
- Labels for restrooms, locker rooms, cafeterias, libraries, conference rooms, mechanical rooms, and other permanent rooms or spaces.



Figure 1-7 Permanent Room Signage

Visual and tactile requirements shall apply to both interior and exterior signage labeling permanent rooms and spaces. However, exterior signage not located at the door to the space they serve shall not have to be tactile but shall meet visual requirements.

1.4 Tactile Signage

Tactile requirements shall apply to these types of signage:

- Interior and exterior signage identifying permanent rooms and spaces.
- Required door labels at exit stairways, exit passageways, and exit discharge.

- Required labels for floor levels, car controls, and emergency communication devices at elevators.



Figure 1-8 Tactile Signage

1.5 Braille Signage

In addition to color contrasts inside buildings, braille signage shall provide a level of accessibility for people who use this system if raised dots in order to read with their fingers. This tactile method shall sometimes be used for labeling objects in the workplace. Braille signage shall provide simple instructions in places such as lifts or toilets- when colour or lighting are not suitable methods of relaying information. They shall also identify hazards in the facility.

Other common applications for braille signage shall include directional arrows, room identification plaques, building zones (particularly in large buildings such as hospitals), exit doors, maps and other aspects of a building that are typically part of wayfinding systems. Braille messages and signage shall be placed particularly at lifts and doors. Tactile maps in particular shall be helpful for visually impaired visitors to assess the layout and scale of a building.

Textured path surfaces shall be used to alert visually impaired visitors to the presence of signage. Since not all visually impaired people shall travel independently outdoors, it shall be useful to include braille on standard information and safety signage for all users.

Inclusion of tactile control buttons and braille signage in lifts shall provide better access for users with visual disabilities is recommended. These tactile approaches are a proactive method of support for people with visual impairments who may prefer to navigate in and around facilities with as much independence as possible.



Figure 1-9 Braille Signage



Braille is located below raised characters, including when text is multi-lined.

Figure 1-10 Braille Signage

1.6 Core Building Signage

The Standards require that tactile and visual signage be provided to identify doors at exit stairways, exit passageways, and exit discharge. Exit passageways are horizontal fire resistance-rated components that lead to exit discharge or public ways. Exit discharge is the path from an exit to a public way.

Exit labels at other locations shall not be required to be tactile but shall meet visual requirements. Life safety and building codes shall address the visibility and illumination of exit signage. At exit doors, the tactile requirements typically shall be met on a separate signage.

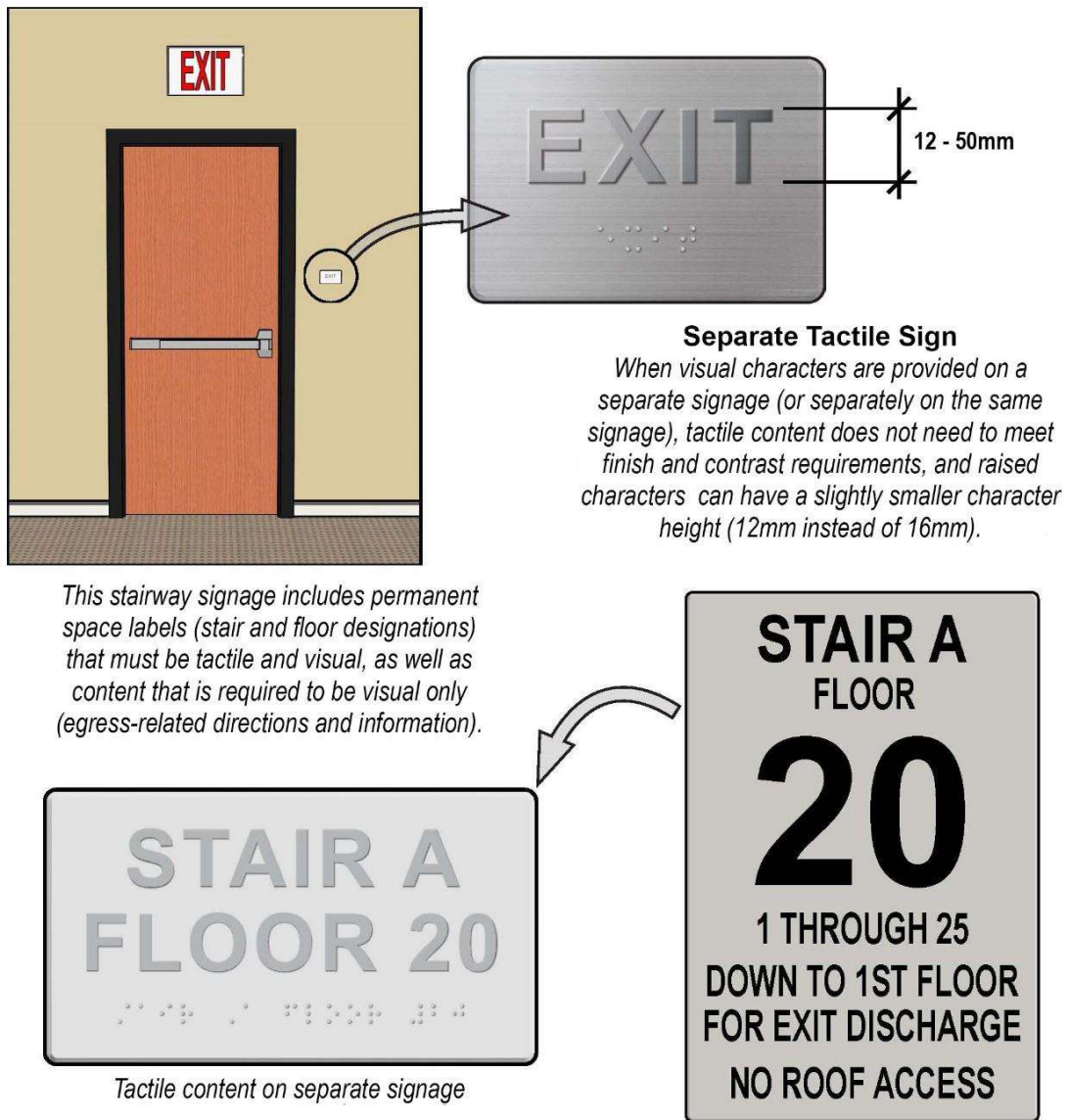


Figure 1-11 Exit Signage

Core Building Signage shall be applied as:

1. Elevator Signage
2. Stairwell Signage
3. Accessibility Signage

1.6.1 Elevator Signage

Every elevator car in every building shall be permanently marked to correspond with the building car position indicator.

The car position indicator shall consist of numbers, letters, or a combination thereof that identifies the position of each elevator car by its shaft in the building relative to the other elevator banks, one

located on the east side of the building and one located on the west side; if each elevator bank consists of four elevators, then car position indicators for that building shall consist of “1E”, “2E”, “3E”, and “4E” for east side elevators, and “1W”, “2W”, “3W”, and “4W” for west side elevators.

The Standards shall require tactile signage (and, in some cases, symbols) at elevators, including labels for:

- Floor designations at elevator hoistways
- Destination-oriented elevator cars.
- Car control buttons
- Emergency communication devices.

For signage at elevators, most of the criteria for raised and braille characters shall apply, but there are differences. For example, raised characters shall be at least 50 mm high on hoistway floor level signage, and tactile content on control panels shall be located outside the standard 1200 - 1500 mm mounting height.



Figure 1-12 Elevator Signage

1.6.2 Stairwell Signage

Stairwell entrances shall be permanently marked to correspond with the stairwell identification.

The identifications shall consist of a combination of letters and numbers that identify the position of the stairwell in the building relative to the other stairwells. If, for instance, a building has two stairways, one on the north and one on the south side of the building, then the identifications shall be marked “N1”, “N2”, “N3”, and “N4” for the north stairwell, and “S1”, “S2”, “S3”, and “S4” for south stairwell, floors one through four respectively.

Stairwell entrances shall be permanently marked to display re-entry location information on the occupancy side (the side where the stairs themselves are located).

1.6.3 Accessibility Signage

Facilities and elements that shall be required to be identified as accessible by **Section 2.11.1** shall use the international symbol of accessibility.

Inaccessible entrances shall have directional signage to indicate the route to the nearest accessible entrance.

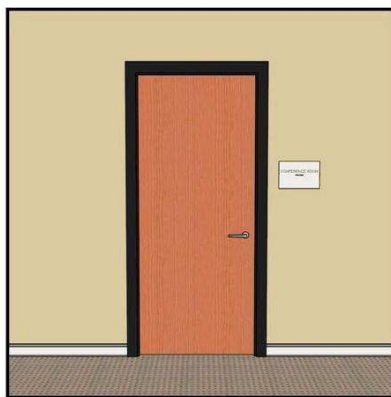
1.7 Instruction and Prohibition Signage

Signage in buildings shall also instruct users to behave in a certain way or prohibit them from undertaking certain activities (“no eating or drinking”). This shall reflect an organization’s internal policies, such as prohibiting the use of mobile phones in certain areas.

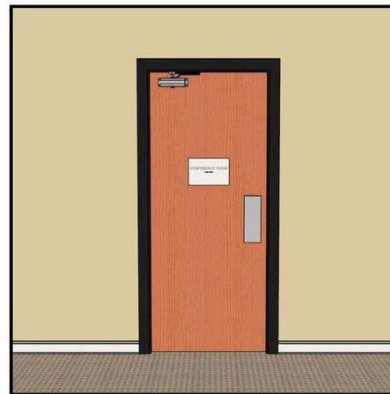
As with other signage, such notices shall convey the necessary information or instruction as clearly and as simply as possible and shall be located where they are easily visible.

1.8 Location at Doors

At single doors, tactile signage shall be located alongside the door on the latch side. They shall be permitted on the push side of doors equipped with closers that shall not have devices to keep them open.



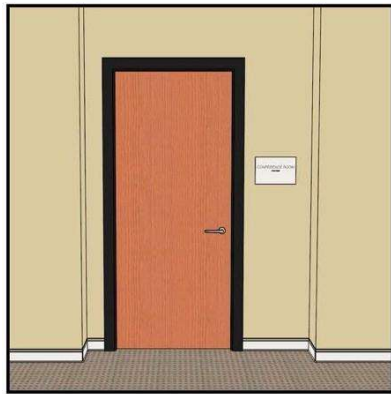
Sign on latch side of single door



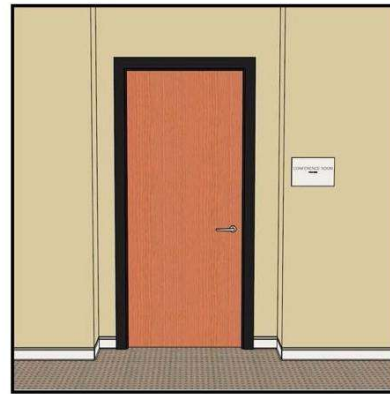
Sign on push side of a door with a closer

Figure 1-13 Signage on a Single Door

If there shall be no wall space on the latch side, signage shall be located on the nearest adjacent wall.



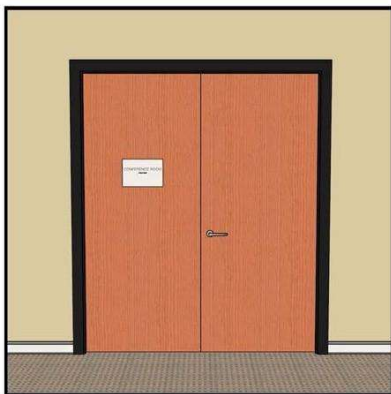
Recessed door with space for latch side placement



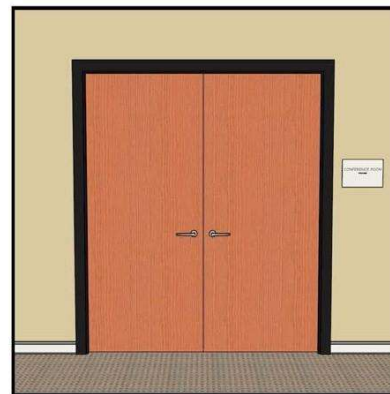
Recessed door with sign on adjacent wall

Figure 1-14 Signage on a Recessed Door

For double-leaf doors with one active leaf, the signage shall be located on the inactive leaf. If each door has an active leaf, the signage shall be located to the right of the door.



Sign on inactive leaf at double-door entry



Sign at right-side hinge side of double-door entry with two active leaves

Figure 1-15 Signage on a Double Leaf Door

1.9 Exemption

The following types of signage shall be exempted and shall not be required to meet visual and tactile requirements:

- Temporary (posted for 7 days or less);
- Building addresses and directories;
- Occupant names and company names and logos;
- Menus;
- Seat or row designations in assembly areas; and
- Signage in non-public areas of detention or correctional facilities.

1.10 Materials and Construction

Signage shall be made from various materials, including:

- Metals- aluminium, stainless steel, metal composites, bronze and brass;
- Plastics- acrylics, polyurethanes, PVC, plexiglass’;
- Timber;
- Backlit and illuminated;
- Digital screens; and
- Fabrics.

Signage shall be elaborate and require complex installation and fixing details depending on scale and size. They shall be a key part of the design process, and not simply left to the end.

2. TECHNICAL REQUIREMENTS

2.1 Character

Upper or lowercase characters (or combination of both), conventional form (prohibited: italic, oblique, script, highly decorative, or other unusual forms)



Figure 2-1 Technical Requirements for Characters



Figure 2-2 Basic Signage Example

2.1.1 Proportion

Characters shall be selected from fonts where the width of the uppercase letter “O” is 55% to 110% of the height of the uppercase letter “I”.

2.1.2 Stroke Thickness

The stroke thickness of the uppercase letter “I” shall be from 10% to 30% of the character height.

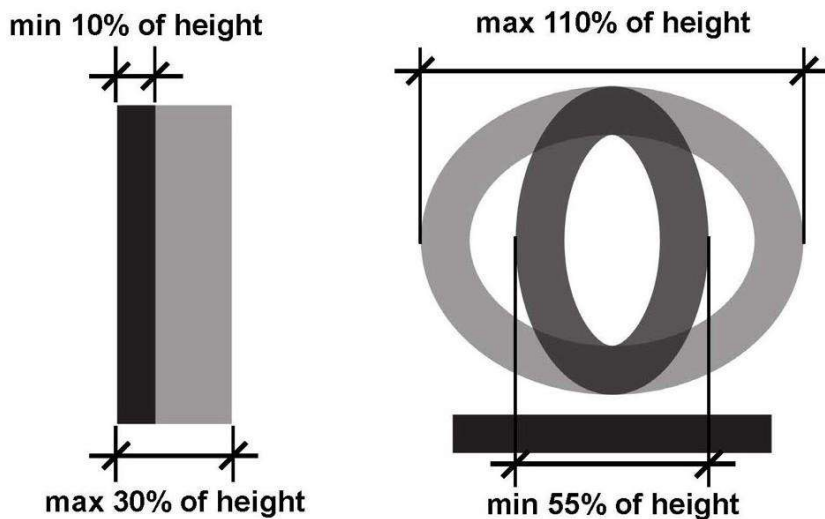


Figure 2-3 Stroke Thickness of Characters

2.1.3 Background

Characters shall contrast with their background with either light-on-dark and have a non-glare finish.

A minimum level of contrast shall not be specified in the Standards. The higher the contrast, the better for legibility, particularly for people with low vision.

Variate or textured backgrounds shall reduce contrast and compromise readability.

2.1.4 Character Size and Space Requirements

Text height shall be of 16 – 50 mm. Character spacing shall be measured between the two closest points of adjacent raised characters within a message, excluding word spaces. Where characters have rectangular cross sections, spacing between individual raised characters shall be 3 mm minimum and 4 times the raised character stroke width maximum.

Where characters have other cross sections, spacing between individual raised characters shall be 1.5 mm minimum and 4 times the raised character stroke width maximum at the base of the cross sections, and 3 mm minimum and 4 times the raised character stroke width maximum at the top of the cross sections.

Characters shall be separated from the raised borders and decorative elements 10 mm minimum.

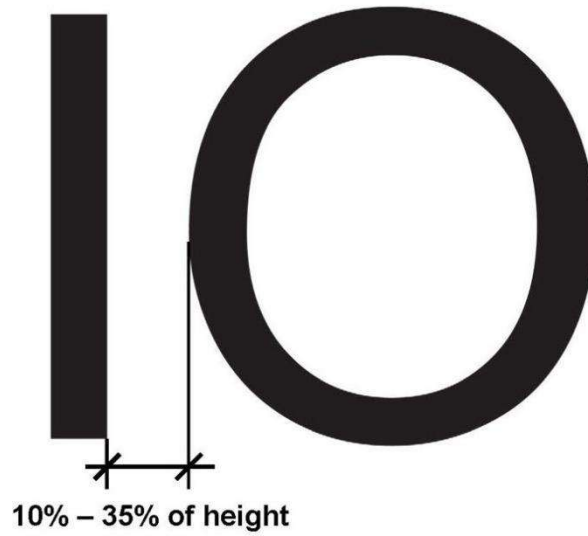


Figure 6-4 Character Spacing

2.1.5 Character Height

The minimum height of characters shall be based on their height above the finish floor and the horizontal viewing distance. Horizontal viewing distance is the distance between the character and an obstruction preventing further approach to the signage.

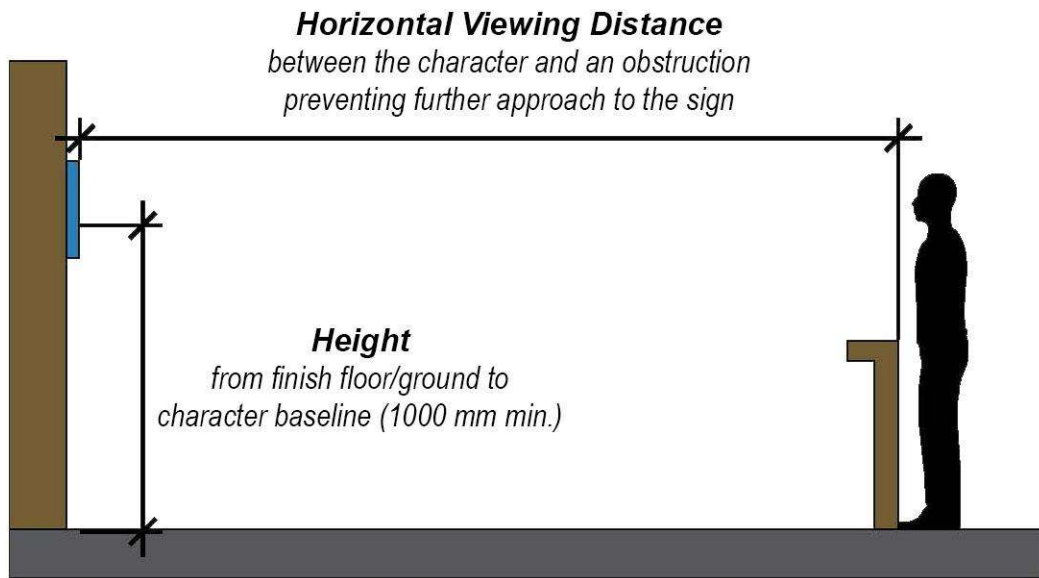


Figure 2-5 Visual Character Height

Table 2-1 Visual Character Height

Height to Finish Floor or Ground from Baseline of Character	Horizontal Viewing Distance	Min. Character Height
1000 mm to less than or equal to 1800 mm	less than 2000 mm	20 mm
	2000 mm and greater	20 mm, plus 5 mm per 500 mm of viewing distance above 2000 mm
Greater than 1800 mm to less than or equal to 3000 mm	less than 4500 mm	50 mm
	4500 mm and greater	50 mm, plus 5 mm per 500 mm of viewing distance above 4500 mm
greater than 3000 mm	less than 6500 mm	75 mm
	6500 mm and greater	75 mm, plus 5 mm per 500 mm of viewing distance above 6500 mm

2.2 Finish and Contrast

When a single set of characters is used to meet requirements for raised and visual characters, the characters and their background shall have a non-glare finish. Characters shall contrast with their background with either light-on-dark or dark-on-light. A minimum level of color contrast shall not be specified, but the higher the contrast, the better, especially for people with low vision. Finish and contrast requirements shall not apply to braille.

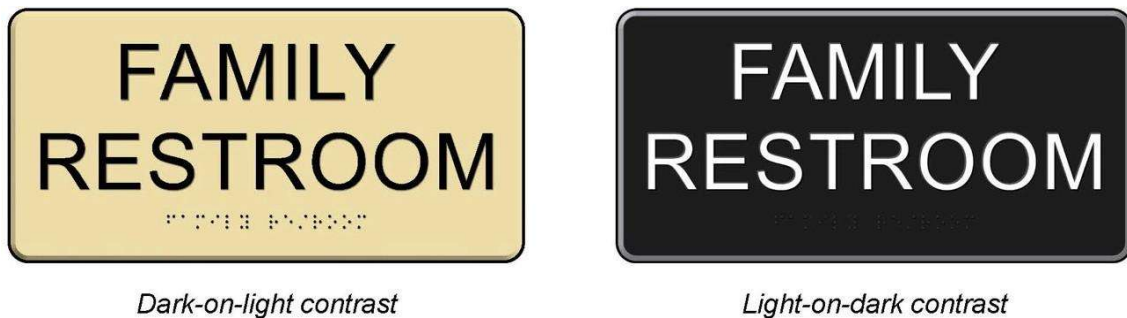


Figure 2-6 Contrast between Characters and Background

2.3 Line spacing

Spacing between the baselines of separate lines of raised characters within a message shall be 135 percent minimum and 170 percent maximum of the raised character height.

2.4 Text

- Use simple, sans serif fonts, in a medium or bold weight.
- Do not use italics, scripts, or other hard-to-read styles.

- For tactile signage, all text must be UPPERCASE.
- For visual only signage, such as directories, directorial signage or overhead signage, you can use lowercase letters.
- Few roman fonts that meet standard guidelines:
 - Helvetica, Futura, Eras. Optima, Avant Garde, Trebuchet, Arial, Verdana, Vag Rounded, Franklin Gothic, Frutiger.
- Few devanagari fonts that meet standard guidelines:
 - Devanagari, Preeti, Adelle Sans Devanagari Regular, Kantipur

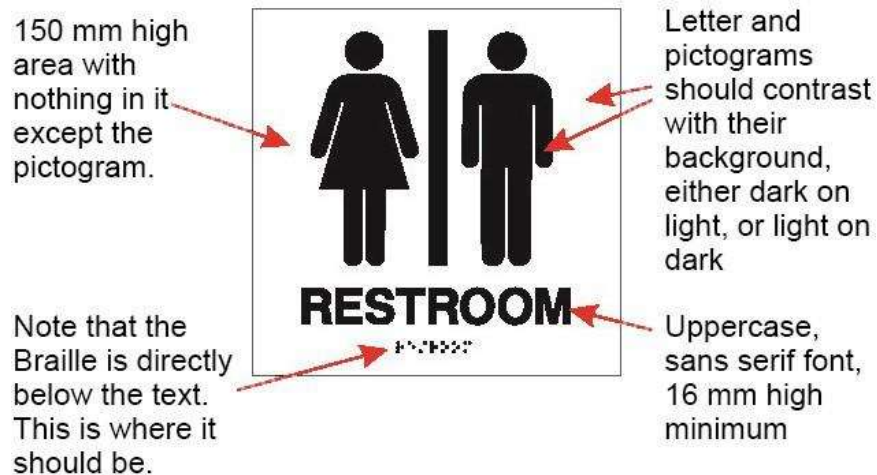


Figure 2-7 Standard Signage

2.5 Devnagari Script

One of the various approaches in describing and defining the anatomy of Devanagari letters uses the body as a reference for the vertical proportion of the letters. The lines defined are as follows:

- i. उ"वरेखा (Top most line)
- ii. शरोरेखा (Head-line)
- iii. +कंधरेखा (Shoulder line)
- iv. नभरेखा (Navel line)
- v. जानुरेखा (Knee position line)
- vi. पदरेखा (Foot line)
- vii. तलरेखा (Extreme bottom line)

Regarding the proportion of letters, the stroke thickness (thickness of the pen stroke shall be used as the base unit. The upper Matra signs shall need a minimum of four strokes and bottom Matras need a minimum of four strokes. Main characters shall require eight strokes, so total 16 units of strokes shall be considered as a primary parameter for the total height as shown in **Figure 2-8**. The thickness of the pen stroke shall be 1/16th of the type height.

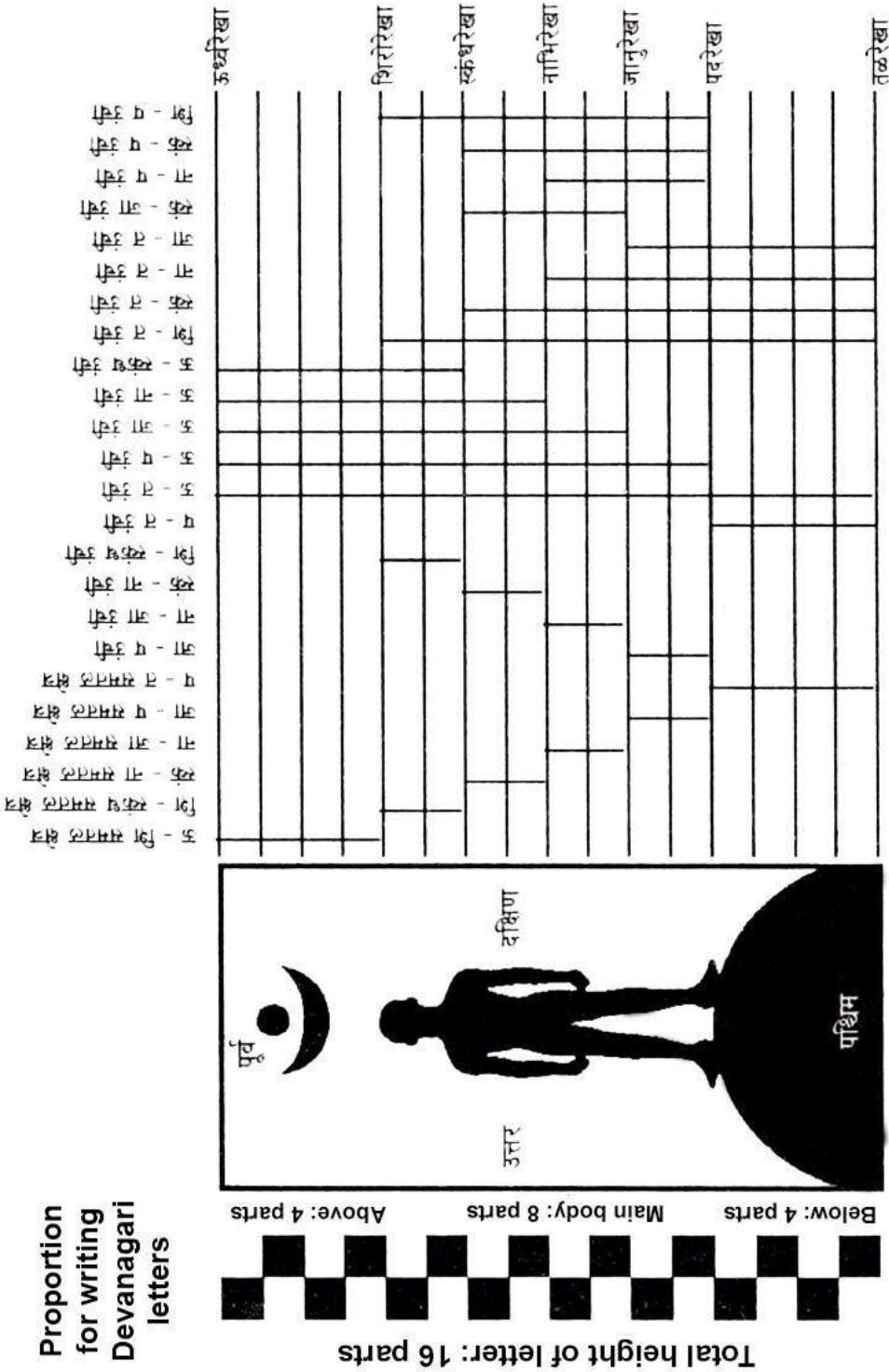


Figure 2-8 Vertical Proportion of Devanagari

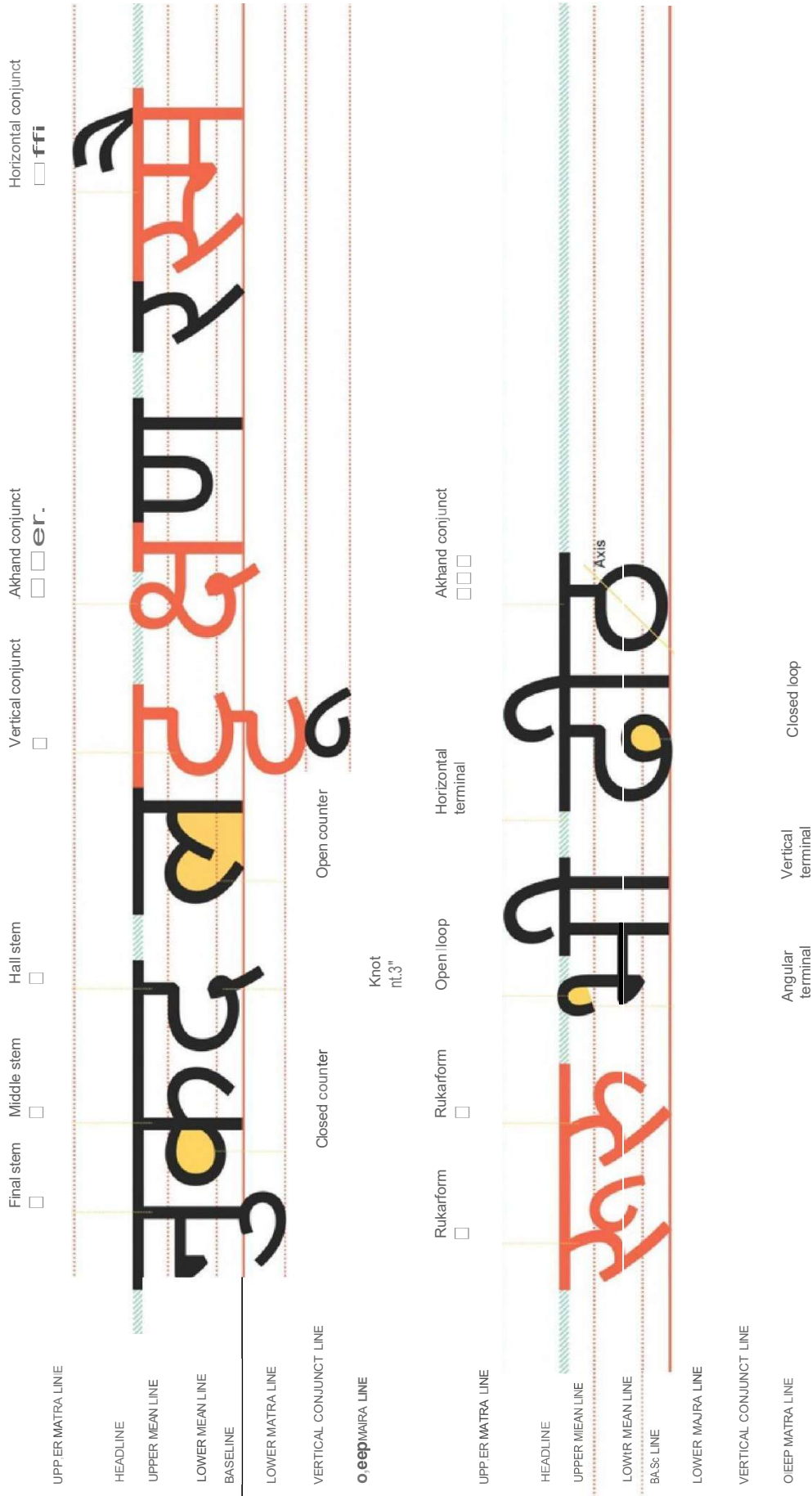


Figure 2-9 Anatomy of Devanagari

2.5.1 Internal Vertical Proportion

Internal Vertical Proportion is the ratio of the height of the Shiro-Rekha to the height of Kana Height. The basic proportion is 1:8. The vertical proportion shall be correlated to the weight and grey value of the typeface. Several measures of vertical proportions for various weights are given below:

- 1:12 for extra-light
- 1:10 for light,
- 1:9 for normal,
- 1:8 for medium,
- 1:7 for semi-bold,
- 1:6 for bold and
- 1:5 for extra-bold

The Gray Value shall be said to be the overall darkness of letters as perceived by typographers.

These recommendations shall be intended for traditional text and calligraphic typefaces, in contemporary typefaces designers practice a great deal of flexibility within these proportions.



Figure 2-10 Internal Vertical Proportion of Devanagari

2.5.2 Vertical Matra Proportion

Vertical Matra Proportion is the ratio of the height of the upper Matra to the kana height to the height of the lower Matra. The recommended ratio is $\frac{1}{2}:1:\frac{1}{2}$ for text typefaces; i.e. if the kana-height is eight strokes then the top and bottom Matras are four strokes. Calligraphic, Display and contemporary fonts shall vary these proportions considerably. In some cases, the lower Matras shall be smaller in proportions than upper Matras because the stroke of upper Matra shall be more complex than the lower Matra.

An approximate rounded off nib-width ratio of the top most Matra shall be considered i.e the maxima of the ai(ळ), au(ळ) Matras or the reph/rafar; for the lower Matras the lowermost line of the Ukar Matras(ळ , ळ), or the Rukar is considered in approximate nib-widths or in proportion with the kana height.



Figure 2-11 Vertical Matra Proportion of Devanagari

2.5.3 Vertical Total Proportion

Vertical Total Proportion: The height of a Devanagari font is not completely defined by the vertical Matra proportions. Several key letters, glyphs, conjuncts, diacritical and vocalization and cantillation marks shall be required to make a complete typeface. Vedic manuscripts shall contain several complex vertically stacked conjuncts which shall be often combined with dependent vowel signs, vocalization and punctuation marks. Implementation of complex top Vedic Cantillation and tone marks, such as the वै;दक सम+वर अंक, possibly the tallest being the वै;दक +व?रत ऊ"वA शर combined with similar bottom tone marks with vertically stacked conjuncts can lead to an extremely large and highly complex six to eight tiered vertical grid. The total internal ratio is defined as the total vertical proportion for a given typeface (topmost glyph to kana height to lowermost glyph height). Here many times the amount of space allotted to the lower Marta of a conjunct is larger than that of the upper Matra.

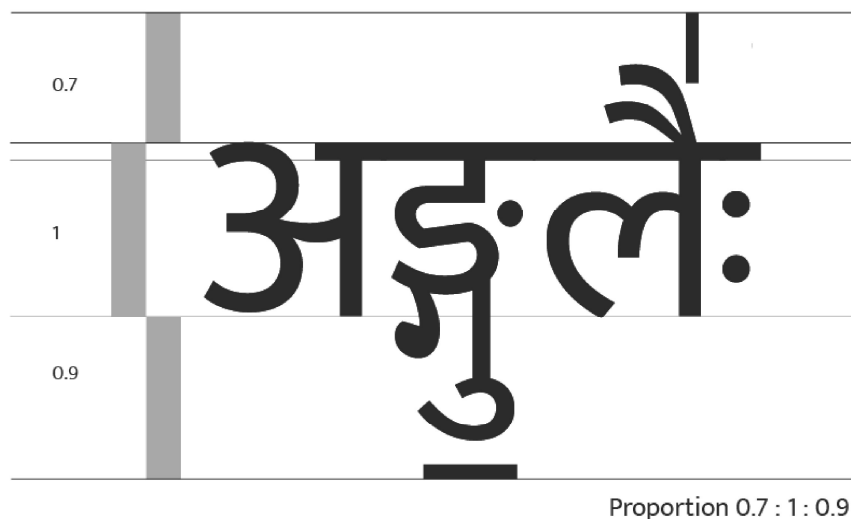


Figure 2-12 Vertical Total Proportion of Devanagari

2.5.4 Horizontal Proportion

The Horizontal Proportion is the proportion of the width of the letters. Common among these are, condensed, regular/normal and expanded. Another method of evaluating the horizontal width for a length of a typeface—analogue to the AZ length in Latin typography shall be the AHO (अहो) length. The AHO length is an un-spaced string containing a select few high frequency syllables starting from अ to हो.

The complete string is: अ आ उ का एक् कु ग घ घा ज जा ट ण त ता तू द न ना ङ न्ने प क ब भ भा भी म मा मु ऋ य या ये र रा ल ला (ल व वा ष श स सा ह हा हो.

The length shall be measured by writing the above letters and measuring its length by any common scale. This length shall be particularly useful to compare the horizontal economy of space within typefaces.



Figure 2-13 Horizontal Proportion of Devanagari

2.5.5 Glyph Width

Glyph Widths are the width proportions of glyphs within a typeface. There are two types of widths: Fonts which have Varying or Proportional Widths for glyphs, and fonts with Mono-Spaced or Equal Width Glyphs. In current digital typeforms, only Proportional Glyphs shall be seen. Monospaced Fonts were quite common in pre-digital days of printing; typewriters, telex machines and some hot metal compositing machines used fixed-width glyph fonts. Their visual quality shall be inferior—since each glyph shall occupy the same amount of space, the Matras shall suffer the most; hence they shall be rarely seen in digital printing.



Figure 2-14 Glyph Width

2.5.6 Neck Position

Neck / Peg Height (Position) is the height of the neck or peg of the letters, in comparison to that of the shiro-rekha (the width of the pen-tip). The neck height shall be measured from the end of the shiro-rekha to the end of the neck and shall be visually gauged by observing all the pegged letterforms (इ, ई, द, ढ, ड, झ, ठ). This height is proportional to the grey value of the typeface—as the typeface becomes darker, the neck becomes smaller.



Figure 2-15 Neck Position of Devanagari

2.6 Tactile Characters

Letters and numerals shall be raised 0.8 mm minimum, uppercase, Sans Serif or Gotham Medium type and shall be accompanied by grade 2 Braille. Grade 2 is not a “letter for letter” translation of the text; it shall contain 265 contractions, single characters shall be used to represent whole words or group of letters. Accurate translation software is a must.

All Braille shall be lowercase, except proper names (e.g., “Sita Poudel”), letter which are part of a room number (e.g., “105A”), initials, acronyms or before the first word of sentences.

Raised characters shall be at least 16 mm high, but no higher than 50 mm.

A minimum of 10 mm clearance shall be left on all side of Braille.

Exception

- Braille provided on elevator car shall be separated 5 mm minimum and shall be located below or adjacent to the corresponding raised characters or symbols.

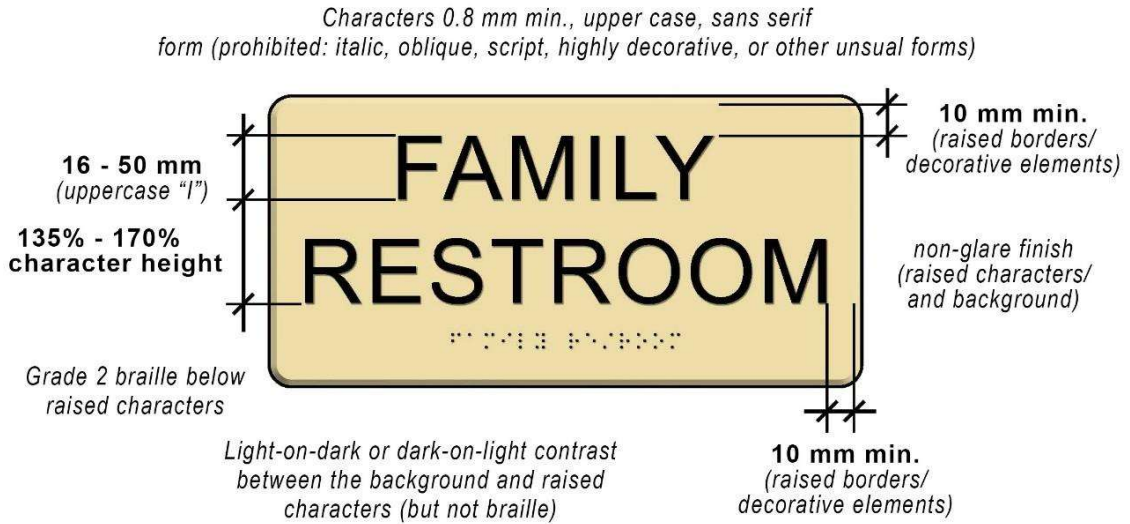


Figure 2-16 Tactile Technical Requirements

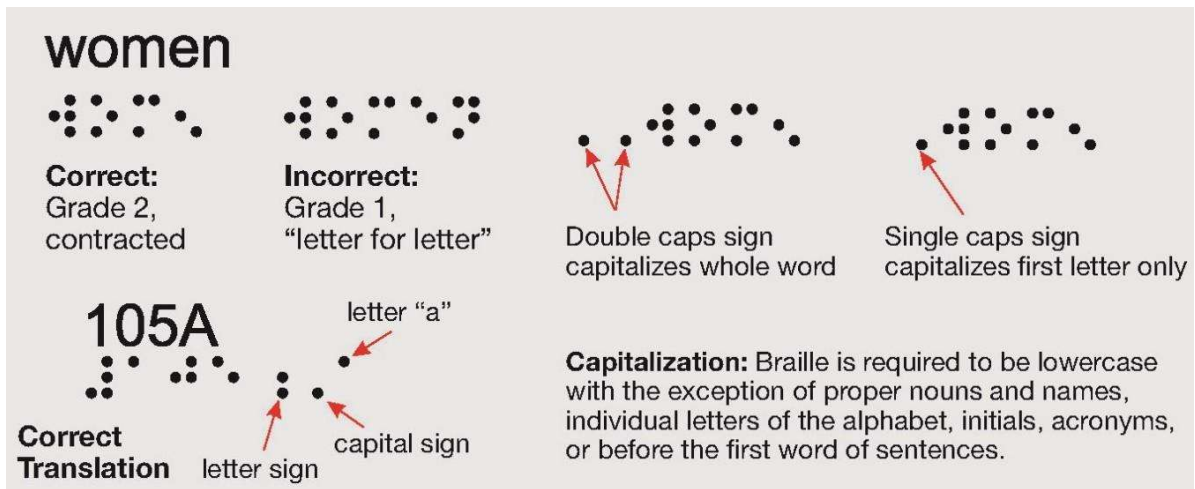


Figure 2-17 Braille Signage

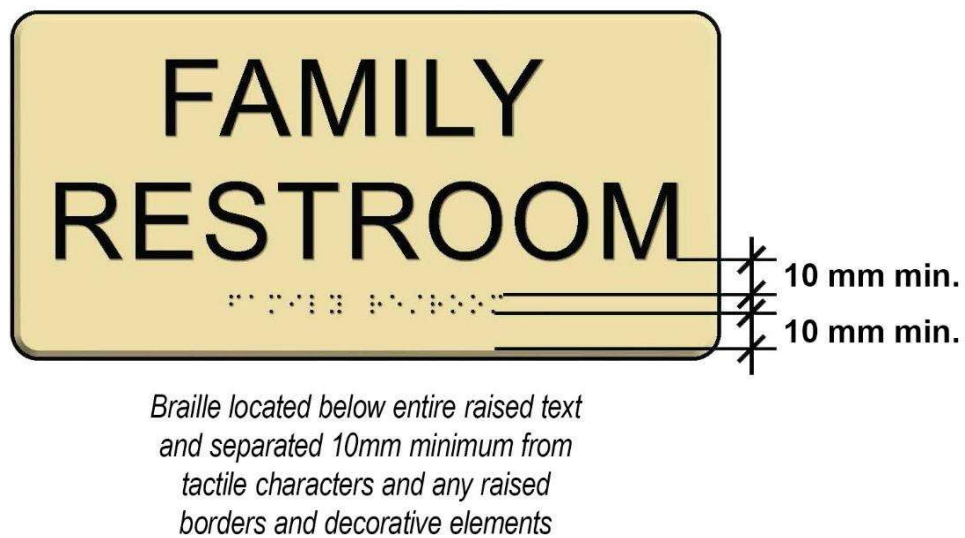


Figure 2-18 Braille Size and Location

Compliant Braille

Braille all together below last line of text



Not Compliant Braille

Braille in two separate locations



Figure 2-19 Braille Compliance

The technical features of braille are given below in **Table 2-2**.

Table 2-2 Braille Dot

Measurement in mm	
Dot Height	0.6 mm to 0.9 mm
Dot Diameter	1.5 mm to 1.6mm
Spacing between dots	2.3 mm to 2.5 mm
Vertical Cell Spacing	10 mm to 10.2 mm
Horizontal Cell Spacing	6.1 mm to 7.6 mm
Dot Shape	Domed or rounded



Braille located below entire raised text and separated 10mm minimum from tactile characters and any raised borders and decorative elements

all dot spacing measured center-to-center

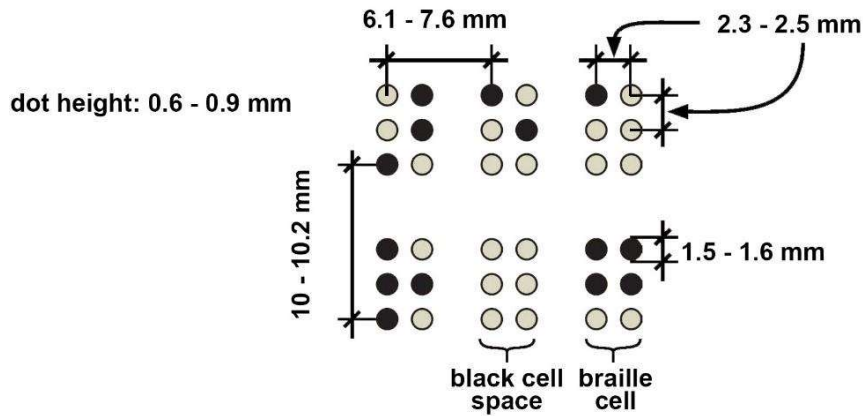


Figure 2-20 Braille Dot Spacing

If visual characters are provided on a separate signage, the tactile signage shall not have to meet finish and contrast criteria and shall have raised characters at 12 mm minimum height.

2.7 Mounting Height and Location

Tactile characters on signage shall be located 1200 mm above the finish floor or ground surface, measured from the baseline of the lowest tactile character and 1500 mm maximum above the finish floor or ground surface, measured from the baseline of the highest tactile character.

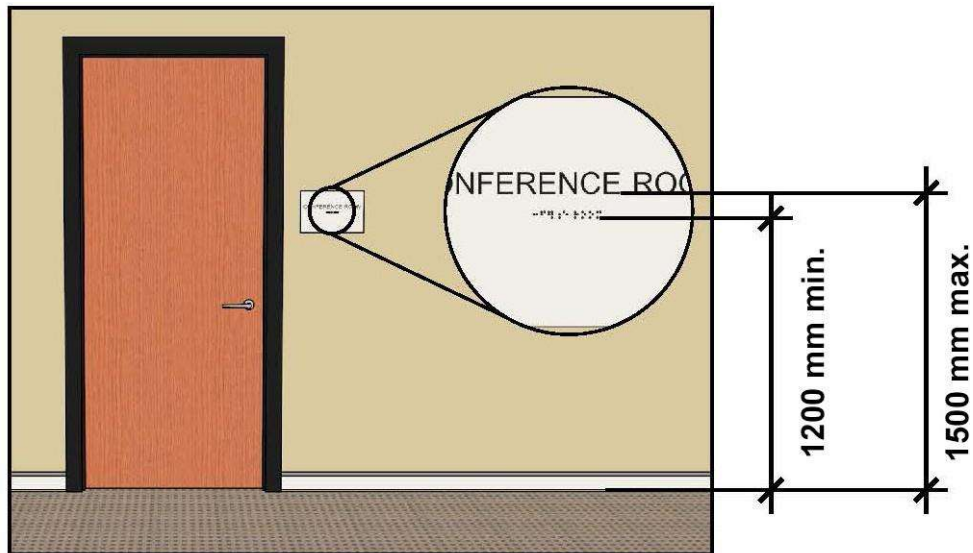
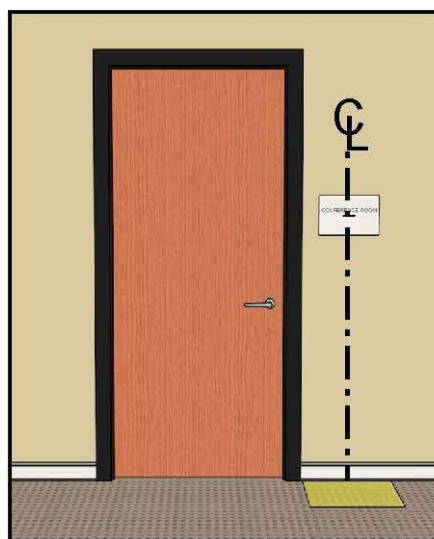


Figure 2-21 Mounting Height of Tactile Characters

Visual characters shall be 1000 mm minimum above the finish floor or ground. Both tactile and visual characters for elevator car controls shall not be required to comply with **Section 2.7**.

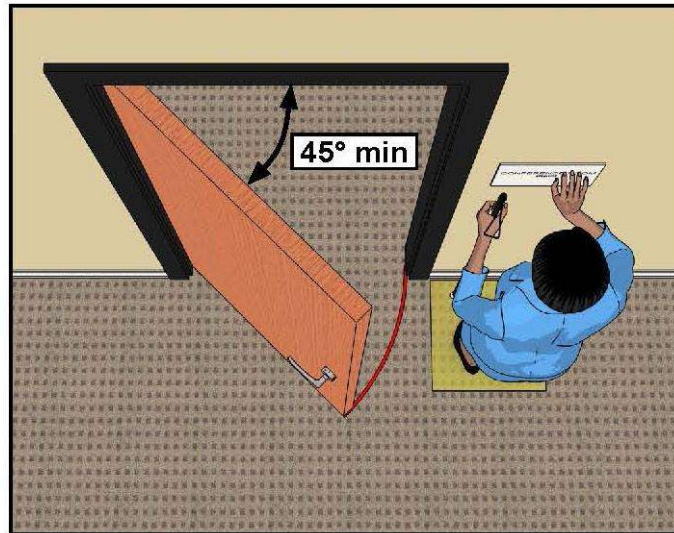
A clear floor space 450 mm minimum by 450 mm minimum shall be centered on the tactile characters as shown in **Figure 2-22**. This placement of the clear floor space provides unobstructed standing space at the signage for reading by touch. This space must be free of any protrusions to a height of 2000 mm.

For safety, the space must be located beyond the arc of any door swing to a 45° open position as shown in **Figure 2-23**. This effectively shall set a minimum, but not an absolute, distance of tactile signage from out-swinging doors. While the clear floor space shall be centered on the tactile characters, signage shall be located varying distances beyond the door swing.



450 mm x 450 mm clear floor space centered on tactile characters

Figure 2-22 Clear Floor Space on Tactile Characters



This clear floor space must be beyond the swing of any door from a closed position to a 45° open position.

Figure 2-23 Clear Floor Space on Tactile Characters

2.8 Pictograms

Pictograms shall be a 150-mm-high area for a pictogram as shown in **Figure 2-24**. There are no rules regarding the actual height of the pictogram, but 100 - 115 mm shall be a good starting point.

Pictograms shall be accompanied by the equivalent verbal description placed directly below the pictogram; the border dimension of the pictogram shall be 150 mm minimum in height.

The pictograms and fields shall have a non-glare finish and a light-on-dark or dark-on-light contrast.

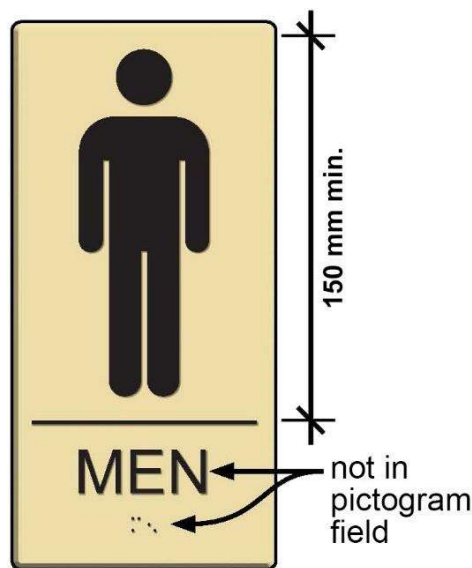


Figure 2-24 Pictogram Size

2.8.1 Informational Pictograms

- Pictograms that provide information about a room or space or that are on directional signage, including accessibility symbols, shall not be required to provide tactile text descriptors or to be located on a field at least 150 mm high.

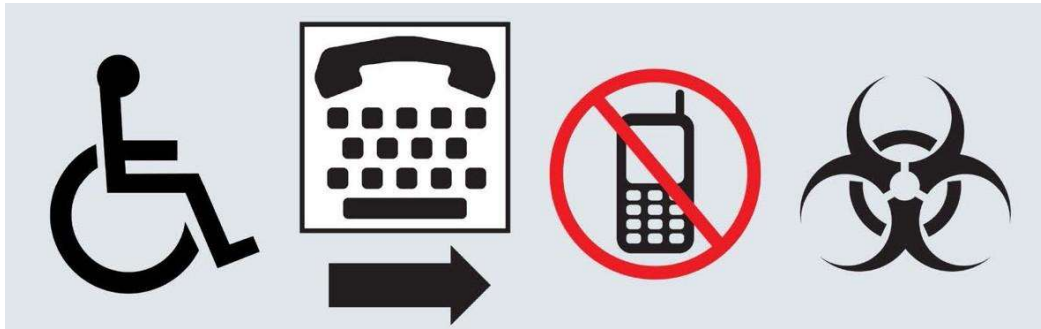


Figure 2-25 Informational Pictogram

2.9 Color

All signage background color shall be as per type of signs. See **Section 1**. The signs shall need to be readable but shall also complement the interior of the building.

The requirement is minimum Light Reflective Value (LRV) difference to be 70 between the sign background and the text legends. Black and white shall provide the greatest contrast but shall sometimes be a problem due to the extreme contrast, so white lettering on a darker background with a matt finish shall provide a good legibility. Use of other colors shall be kept simple using only 6 of the basic colour range- white, grey, orange, blue, green and red.

Exceptions:

- "Fire Extinguisher" sign background shall be Red
- "Emergency Eyewash/Shower" sign background shall be Green.

2.10 Icons

This range of icons shall be used to supplement the text legends to aid the legibility and understanding of signs. In particular, these shall be used to highlight lifts, stairs, accessible routes, toilets and information. These shall be based on internationally recognized pictograms as shown in **Figure 2-26**.

Accessible toilets shall need to additionally identify if the toilet is a left hand (LH) or right hand (RH) transfer.



Figure 2-26 Internal Icon Style

2.11 Symbols

2.11.1 International Symbol of Accessibility (ISA)

The International Symbol of Accessibility shall comply with **Figure 2-27**.



Figure 2-27 International Symbol of Accessibility

The ISA shall be used to label, or provide direction to, these elements and spaces (unless all are accessible):

- Entrances
- Toilet rooms and bathing room’s parking
- Check-out aisles

- Existing compliant elevators

2.11.2 International Symbol of TTY

The International Symbol of TTY shall comply with **Figure 2-28**.

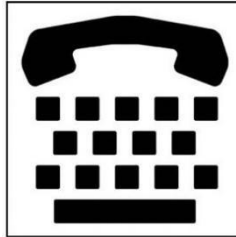


Figure 2-28 International Symbol of TTY

Some public payphones, where provided, shall be equipped with TTYs to provide communication access for people with hearing or speech impairments. The International Symbol of TTY shall be used to identify TTY-equipped phones.

Directional signage indicating the location of the nearest TTY shall be provided at phonebanks without TTYs. Additionally, where directional signage to public pay phones are provided, signs shall also be provided to public TTYs. These directional signage shall include the International Symbol of TTY and meet visual criteria in the Standards.

2.11.3 International Symbol of Access for Hearing Loss

The International Symbol of TTY shall comply with **Figure 2-29**.



Figure 2-29 International Symbol of Access for Hearing Loss

Signage with the International Symbol of Access for Hearing Loss and compliant with the visual criteria shall be required to indicate the availability of assistive listening systems in assembly areas. These systems shall enhance sound signals for people who are hard of hearing and shall be provided in assembly areas equipped with audio amplification and in courtrooms. Signage shall be provided at each assembly area or each ticket office or window. Verbiage on signage shall not be specified, but it shall be helpful to indicate where assistive listening devices can be acquired.

3. GENERAL RULES

3.1 Naming

The hierarchy of sign destinations shall be considered and as rule, shall sign the general first and the specific later. So, within a building that would mean signing to a department, then to a floor, then a room. Important spaces/ junctions/ floors shall be better sign to, rather than all the locations near those spaces. So, it shall be important to identify the key routes and orientation spaces within a building, for example in buildings where there are wings, these shall be named, primary halls / corridors which act as main orientation points should also be named. In this way signs shall be kept to a minimum.

In addition, signage shall identify the step free routes. The primary routes shall follow the step free entrance wherever possible.

Simpler set of destinations to areas/ zones may be better with more detailed information developing as specific destinations shall be approached.

When identifying departments, it shall be best to sign to the departmental office as this shall be the department's front door. If the department shall cover a number of floors, it shall not be necessary to sign the department on each floor, but just the key spaces like lecture theatres, meeting rooms etc, and then shall identify the group of offices e.g., offices 101- 109.



Figure 3-1 Naming

3.2 Floor Levels

Floor numbers shall need to be signed at points of changing between levels such as at stairs and lifts, but also the floor number shall be shown on the directory panels.

The default identification shall be:

G- Ground Floor

1,2, 3 etc.- upper floors

-1, -2 etc. for below ground levels.

The Floor number/ letter shall be shown in the top right-hand corner of the signage.

A sensible approach shall need to be taken to ensure room numbers and floor numbers match, and that where buildings join each other that the floor numbers shall be consistently applied as one travels between buildings.

In some instances, there shall also be intermediate floor introduced and these shall be named mezzanine, and if there shall be several intermediate floors throughout a building then name the mezzanine so it shall relate to the floor it is just above, e.g., a mezzanine between ground and first floor shall be Ground Mezzanine. (See **Figure 3-2**).



Figure 3-2 Floor Level

3.3 Arrows

A uniform and simple arrow type shall be used on all signs. The size of the directional arrows shall be set in the artwork; however, the correct arrow and legend configuration shall be used on all signs.



Figure 3-3 Arrow

The arrow shall be one of the most useful symbols used in signage, and when used correctly aids legibility and understanding. Text legends shall be aligned according to the direction of the arrow.

The arrows shall always point towards the location being directed to, not into text. The arrows on signage shall be clear and easy to see. It's better to group the information to make signage cleaner.

4. GENERAL MINIMUM REQUIREMENTS

4.1 Health and/ or Safety Signage at Work

Health and/or safety signage shall be used only to convey the message or information specified in the report.

4.1.1 Permanent Signage

Permanent signboards shall be used for signage relating to prohibitions, warnings and mandatory requirements and the location and identification of emergency escape routes and first-aid facilities.

Signboards and/or a safety color shall be used to mark permanently the location and identification of fire-fighting equipment.

Safety color and/or with signboards shall be used permanently in places where there shall be a risk of colliding with obstacles or of falling, and also in traffic routes.

4.1.2 Occasional Signage

Illuminated signage, acoustic signals and/or verbal communication shall be used where the occasion requires, taking into account the possibilities for interchanging and combining signage set out in **Section 4.1.3** to signal danger, to call persons to take a specific course of action and for the emergency evacuation of persons.

Hand signals and/or verbal communication shall be used where the occasion requires, to guide persons carrying out hazardous or dangerous maneuvers.

4.1.3 Interchanging and Combining Signage

Any one of the following shall be used if equally effective:

- A safety color or a signboard to mark places where there is an obstacle or a drop;
- Illuminated signage, acoustic signals or verbal communication;
- Hand signals or verbal communication.

Some types of signage shall be used together:

- Illuminated signage and acoustic signals;
- Illuminated signage and verbal communication;
- Hand signals and verbal communication.

4.1.4 Safety Color

The instructions in the table below apply to all signage incorporating a safety color as shown in **Table 4-1**.

Table 4-1 Safety Color

Colour	Meaning or Purpose	Instructions and Information
Red	Prohibition sign	Dangerous behavior
	Danger alarm	Stop, shutdown, emergency cutout devices Evacuate
	Fire-fighting equipment	Identification and location
Yellow or Amber	Warning Sign	Be careful, take precautions Examine
Blue	Mandatory Sign	Specific behavior or action Wear personal protective equipment
Green	Emergency escape, first aid sign	Doors, exits, routes, equipment, facilities
	No danger	Return to normal

4.1.5 Effectiveness of a Signage

The effectiveness of a signage shall not be adversely affected by:

- The presence of another emission source of the same type which shall interfere with visibility or audibility; therefore, in particular.
 - The placing of too many signage too close together shall be avoided.
 - Two illuminate signage which shall likely to be confused are not to be used at the same time.
 - An illuminated signage shall not be used in the proximity of another similar illuminated source
 - Two acoustic signals shall not be used at the same time
 - An acoustic signal shall not be used if there is too much ambient noise
- Poor design, insufficient number, incorrect positioning, poor state of repair or incorrect functioning of the signage or signaling devices.

4.1.6 Other Requirements

Depending on requirements, signage and signaling devices shall be cleaned, maintained, checked, repaired, and if necessary, replaced on a regular basis to ensure that they retain their intrinsic and/or functional qualities.

The number and positioning of signage or signaling devices to be installed shall depend on the extent of the hazards or dangers or on the zone to be covered.

Signage requiring some form of power shall be provided with a guaranteed emergency supply in the event of a power cut, unless the hazard has thereby been eliminated.

The triggering of an illuminated signage and/or acoustic signal shall indicate when the required action should start, the signage or signal shall be activated for as long as the action requires.

Illuminated signage and acoustic signals shall be reactivated immediately after use. Illuminated signage and acoustic signals shall be checked to ensure that they function correctly and that they are effective before they are put into service and subsequently at sufficiently frequent intervals.

If the hearing or the sight of the workers concerned is impaired, including impairment caused by the wearing of personal protective equipment, measures shall be taken to supplement or replace the signage concerned.

Areas, rooms or enclosures used for the storage of significant quantities of hazardous substances or mixtures shall be indicated by a suitable warning signage taken from **Section 4.1.3**. unless the labelling of the individual packages or containers is adequate for this purpose. If there is no equivalent warning signage in **Section 4.1.3**. to warn about hazardous chemical substances or mixtures, the relevant hazard pictogram shall be used.

4.2 Signboards

4.2.1 Intrinsic Features

The shape and colors of signboards are set out in **Section 4.1**, in accordance with their specific object (signboards indicating a prohibition, a warning, a mandatory action, an escape route, an emergency or fire- fighting equipment).

Pictograms shall be as simple as possible and shall contain only essential details. The pictograms used shall be slightly different from or more detailed than those shown in **Section 4.1**, provided that they shall convey the same meaning and that no difference or adaptation shall obscure the meaning.

Signboards shall be made of shock and weather-resistant material suitable for the surrounding environment. The dimensions and colorimetric and photometric features of signboards shall be such that they shall be easily seen and understood.

4.2.2 Conditions of Use

Signboards shall be in principle to be installed at a suitable height and in a position appropriate to the line of sight, taking account of any obstacles, either at the access point to an area in the case of a general hazard, or in the immediate vicinity of a specific hazard or object and in a well-lit and easily accessible and visible location.

The signboard shall be removed when the situation to which it refers ceases to exist.

4.2.3 Signboards to be Used

4.2.4 Prohibitory Signage

- Refer to **Section 1.1.2**

4.2.5 Warning Signage

- Refer to **Section 1.1.1**

4.2.6 Mandatory Signage

- Refer to **Section 1.1.3**

4.2.7 Emergency Escape or First-aid Signage

- Refer to **Section 1.1.4**

4.2.8 Fire-Fighting Signage

- Refer to **Section 1.1.5**

4.3 Fire-Fighting Equipment

Specific color shall be used to identify fire-fighting equipment. Placement of a location signboard and a specific color shall be used for the places where such equipment is kept, or their access points.

The color for identifying this equipment shall be red. The red area shall be sufficiently large to allow the equipment to be identified easily. The signboards provided for in **Section 1.1.5** shall be used to mark the locations of this equipment.

4.4 Obstacles and Dangerous Locations

4.4.1 Signage for obstacles and dangerous locations

Places where there shall be a risk of colliding with obstacles, of falling or of objects falling should be marked with alternating yellow and black, or red and white stripes in built-up zones in the undertaking to which workers have access during their work.

The dimension of the markings shall be commensurate with the scale of the obstacle or dangerous location in question. The yellow and black or red and white stripes shall be at an angle of approximately 45° and of more or less equal size as shown in **Figure 4-1**.



Figure 4-1 Signage for Obstacles and Dangerous Location

4.4.2 Marking of Traffic Routes

Where the use and equipment of rooms so requires for the protection of workers, traffic routes for vehicles shall be clearly identified by continuous stripes in a clearly visible color, preferably white or yellow, taking into account the color of the ground.

The stripes shall be located so as to indicate the necessary safe distance between the vehicles and any object which may be nearby, and between pedestrians and vehicles.

Permanent traffic routes in built-up areas outdoors should, as far as is practicable, shall be similarly marked, unless they are provided with suitable barriers or pavements.

4.5 Illuminated Signage

4.5.1 Intrinsic features

The light emitted by a signage shall produce a luminous contrast which is appropriate to its environment, in accordance with the intended conditions of use of the signage, but without producing glare for an excessive amount of light or poor visibility as a result of insufficient light.

The luminous area emitting a signage shall be of a single color or contain a pictogram on a specified background. The single color shall correspond to the table of colors and their meanings set out in **Table 4-1**. Likewise, when the signage shall contain a pictogram, the latter shall comply with all the relevant rules set out in **Section 4.2**.

4.6 Acoustic Signage

4.6.1 Intrinsic features

Acoustic signals shall:

- have a sound level which is considerably higher than the level of ambient noise, so that it is audible without being excessive or painful;
- be easily recognizable, particularly in terms of pulse length and the interval between pulses or groups of pulses, and be clearly distinct from any other acoustic signal and ambient noises.

If a device can emit an acoustic signal at variable and constant frequencies, the variable frequency shall be used to indicate a higher level of danger or a more urgent need for the requested/imposed intervention or action in relation to the stable frequency.

4.6.2 Code

The signal for evacuation shall be continuous.

4.7 Signage for People with Disabilities

Signage for people with disabilities should be designed with accessibility in mind. The following are some general guidelines to consider:

Use high-contrast colors: Use high-contrast colors for the text and background. For example, use black or dark text on a white or light background. Avoid using color combinations that are hard to read, such as red on green.

People with low vision find egg crate color background, with black/dark lettering, as high contrast color can cause discomfort to eyes.

In general, signs should not be placed behind glass because of possible reflection.

- Use large text and symbols:
- Use clear, easy-to-read fonts, and not decorative or fancy fonts.
- Use a minimum of 16-point font size to ensure that the text is large enough to be easily read by most people. However, for people with visual impairments, larger text sizes may be needed. The letter height should not be less than 15 mm.
- Use Braille and tactile signage
- Use international symbols for accessibility.
- The wheelchair figure should always be seen from drawn facing right

Pictorial signage on instruction on how to use toilet and basin area should be added, so that it will help people with autism.

5. MOUNTING GUIDELINES

The different types of mounting guidelines are mentioned below:

5.1.1 Unobstructed

Where permanent identification is provided for rooms and spaces, signage shall be installed on the wall adjacent to the latch side of the door, or the call button side of elevator door.

5.1.2 Obstructed.

Where there is no wall space adjacent to the latch side of the door, including at double leaf doors, signage shall be placed on the nearest adjacent wall.

5.1.3 Side light.

Where there is a sidelight adjacent to the latch side of the door, signage shall be placed on the sidelight, 50 mm from latch side of the sidelight frame, and a vinyl backer shall be applied to the glass surface.

5.1.4 Overhead Signage.

Mounting height for all overhead or cantilevered signage shall be 2000 mm above the finished floor to the bottom of the signage.

5.2 Mounting Options

The effectiveness and application of each option shall always be tested before actual installation. In most cases, a good silicone adhesive is also recommended when mounting signage.

5.2.1 Double Faced Foam Type

- It is 1.5 mm pressure sensitive foam tape.
- It is best used in conjunction with silicone adhesive.

5.2.2 Double Faced Tape- Red

- It is thin 1.5mmHg pressure sensitive tape.
- It is applied on flat, smooth surfaces.

5.2.3 Screw Holes- Torx

- It is 4.5 mm screw holes with optional 38 mm vandal resistant button torx.'

5.2.4 Partition Hook

- Custom acrylic hooks available in black, white or clear for any size partition.

5.2.5 Velcro Hook (Loop)

- For fabric surfaces such as office workstations.
- Always test first.

5.2.6 Magnetic Tape (Foil)

- 0.8 mm magnetic tape for steel surfaces or removable panels.

5.2.7 Wall or Ceiling Bracket

- Anodized aluminum bracket in satin silver used for flag mounted or ceiling mounted signage.
- Sizes: 150mm, 225 mm, 275 mm

5.2.8 Counter Bracket

- Anodized aluminum bracket in satin silver used for counter top or workstation signage.
- Sizes: 50mm, 225 mm, 275 mm

6. STANDARD SIGNAGE TEMPLATES

List of Templates

Internal Signage Templates

- Signage Type A1: Room I.D.
- Signage Type A2: Room I.D.
- Signage Type A3: Room I.D.
- Signage Type A4: Room I.D.
- Signage Type A5: Department I.D.
- Signage Type A6: Room I.D.
- Signage Type A7: Room I.D.
- Signage Type A8: Suite Room I.D.
- Signage Type A9: Stair
- Signage Type A10: Restroom
- Signage Type A11: Stairwell
- Signage Type A12: Level
- Signage Type A13: Exit
- Signage Type A14: Directories
- Signage Type A15: Directories
- Signage Type A16: Directional
- Signage Type A17: Building Plan
- Signage Type A18: Evacuation Plan
- Signage Type A19: Stair Signage Locations

- Signage Type A20-1: Citizen's Charter
 - Signage Type A20-2: Citizen's Charter
 - Signage Type A20-3: Citizen's Charter
 - Signage Type A21: Information Officer
- Recommended List for Internal Signage

External Signage Templates

- Signage Type E1: Free Standing Monolith
- Signage Type E2: Wall Mounted Signage
- Signage Type E3: Vehicular Directional
- Signage Type E4: Vehicular Directional
- Signage Type E5: Pedestrian Directional
- Signage Type E6: Parking Area I.D.
- Signage Type E7: Site Information
- Signage Type E8: Reserved Parking I.D.
- Signage Type E9: Reserved Parking I.D.
- Signage Type E10: Area I.D.
- Signage Type E11: Accessibility Signage
- Signage Type E12: Street Signage
- Signage Type E13: Street Signage

Signage Type E14: Street Signage

Signage Type E15: Building I.D.

Signage Type E16: Building I.D.

Signage Type E17: Building I.D.

Signage Type E18: Building I.D.

Signage Type E19: Building I.D.

Signage Type E20: Building I.D.

Signage Type E21: Building Information

Recommended List for External Signage

INTERNAL SIGNAGE TEMPLATES

Internal Signage Templates

Signage Type A1

Room I.D.

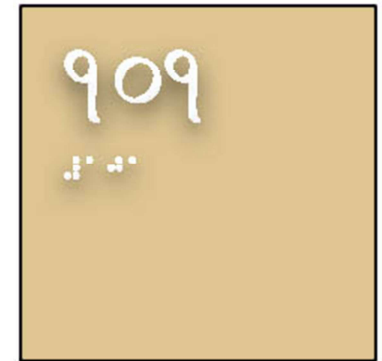
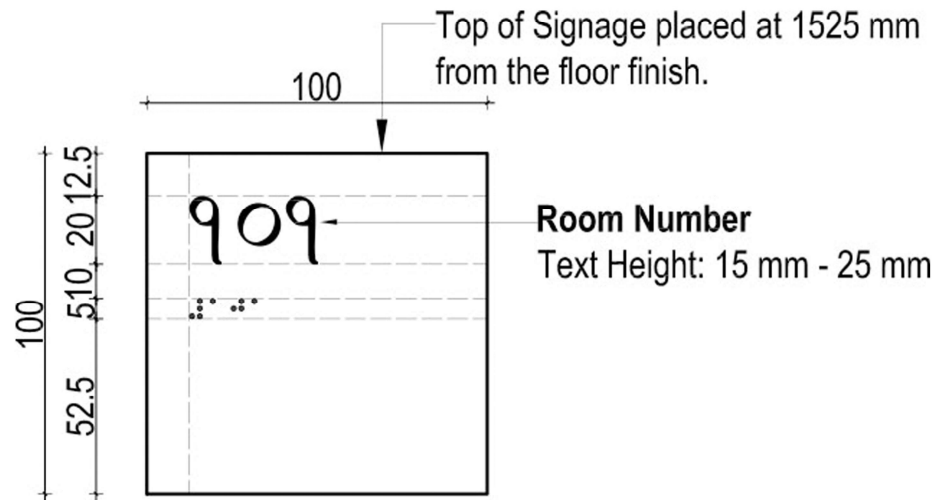
Artwork Dimensions:
100mm (w) x 100mm (h)

Placement:
Top of Signage placed at 1525 mm from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be used to indicate the room number only.



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

275

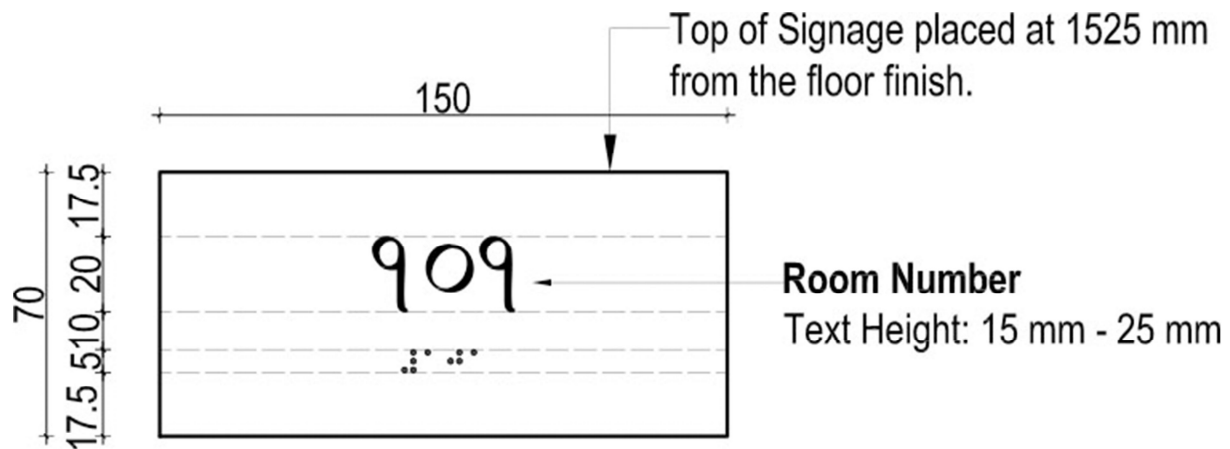
Signage Type A2

Room I.D.

Artwork Dimensions:
150mm (w) x 70mm (h)

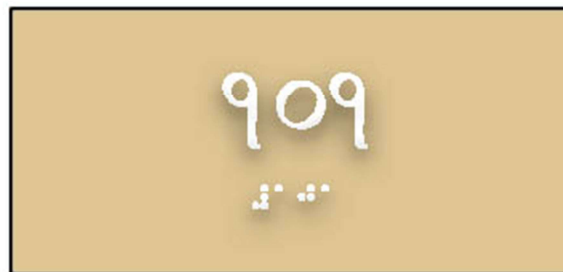
Placement:
Top of Signage placed at 1525 from floor finish.

Font Style:
Preeti



General Notes:

This signage is to be used to indicate the room number only.



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

276

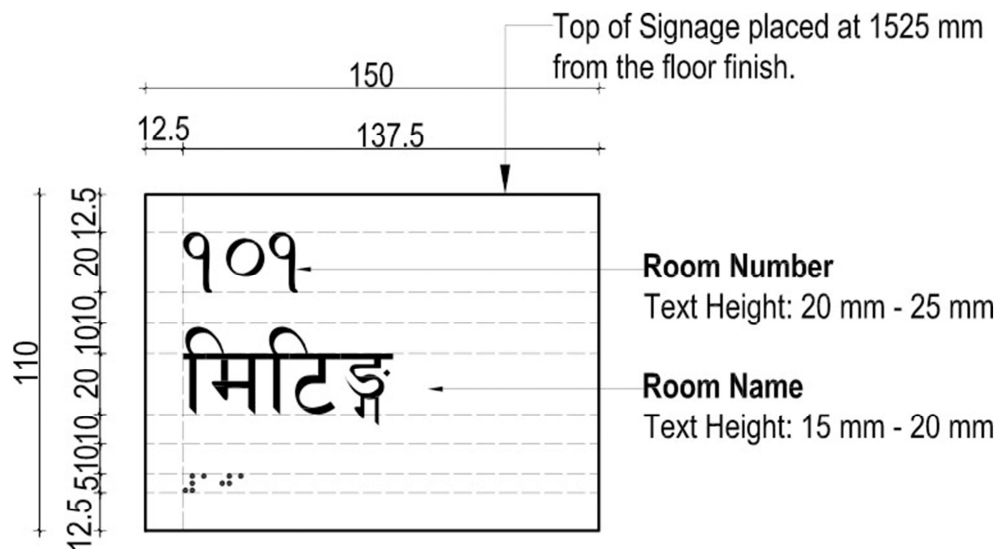
Signage Type A3

Room I.D.

Artwork Dimensions:
150mm (w) x 110mm (h)

Placement:
Top of Signage placed at 1525 from floor finish.

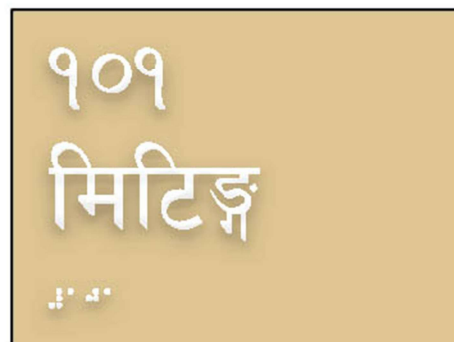
Font Style:
Preeti



General Notes:

This signage is to be used to indicate the room number and type.

Please note: signage dimensions can be adjusted as per type.



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A4

Room I.D.

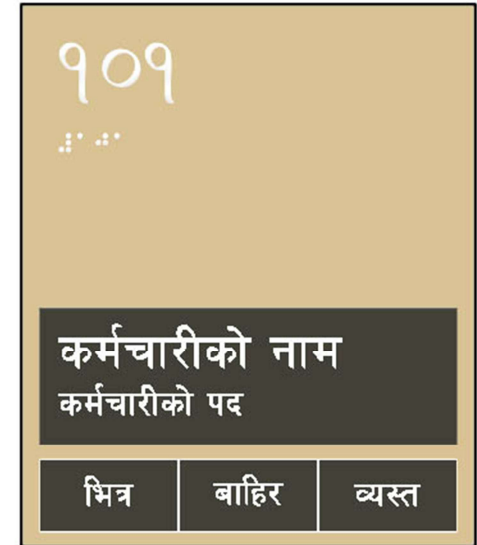
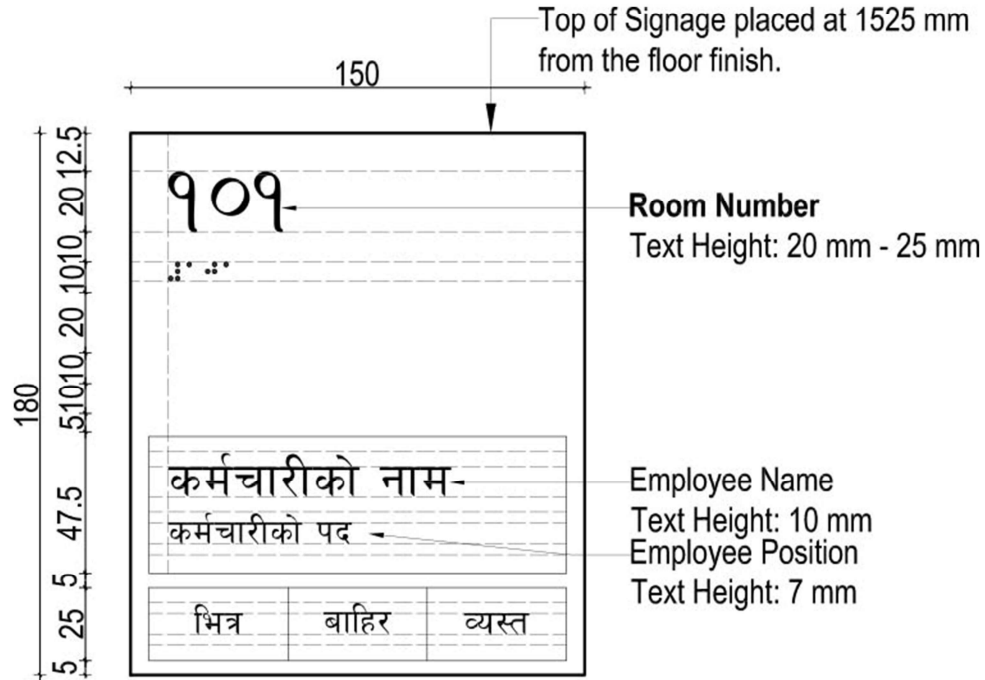
Artwork Dimensions:
150mm (w) x 180mm (h)

Placement:
Top of Signage placed at 1525 mm from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be on or beside a door for all offices. It has room number, employee's name and position.



Please note: signage dimensions can be adjusted as per name and position.

Internal Signage Templates

Signage Type A5

Office I.D.

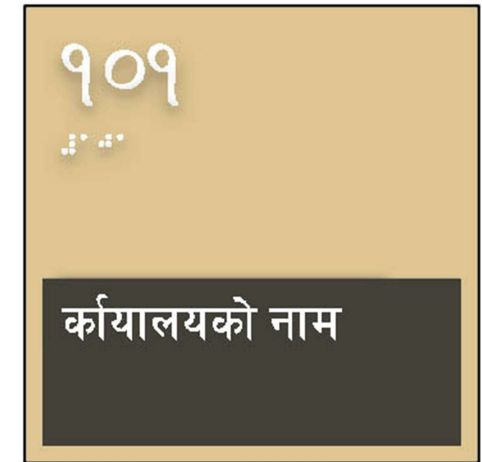
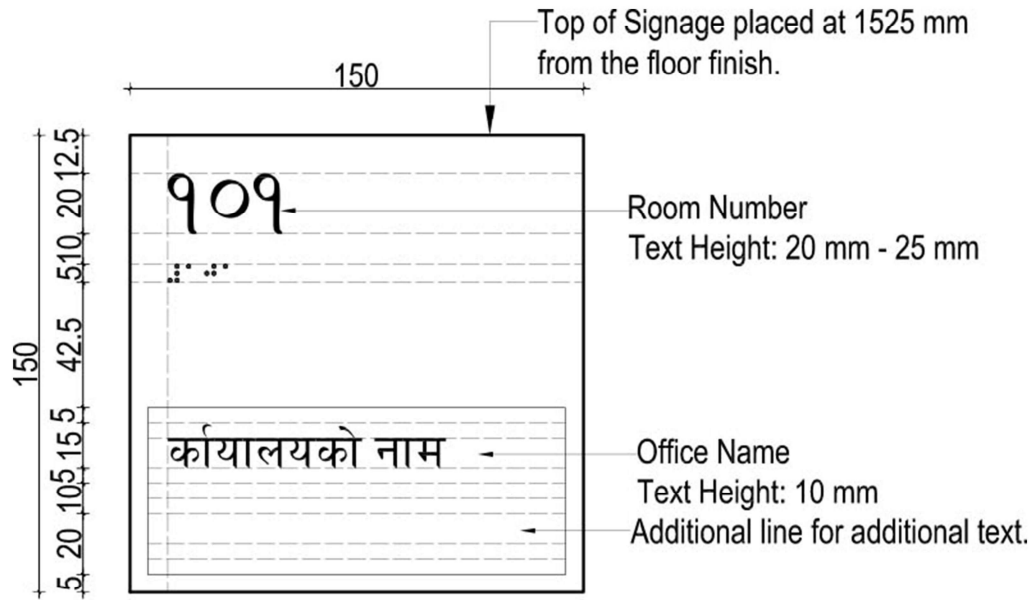
Artwork Dimensions:
150mm (w) x 150mm (h)

Placement:
Top of Signage placed at 1525 mm from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be placed beside the main entrance of office. It has office number and name. Office number on signage is optional.



Please note: signage dimensions can be adjusted as per department name.

Internal Signage Templates

Signage Type A6

Room I.D.

Artwork Dimensions:
150mm (w) x 220mm (h)

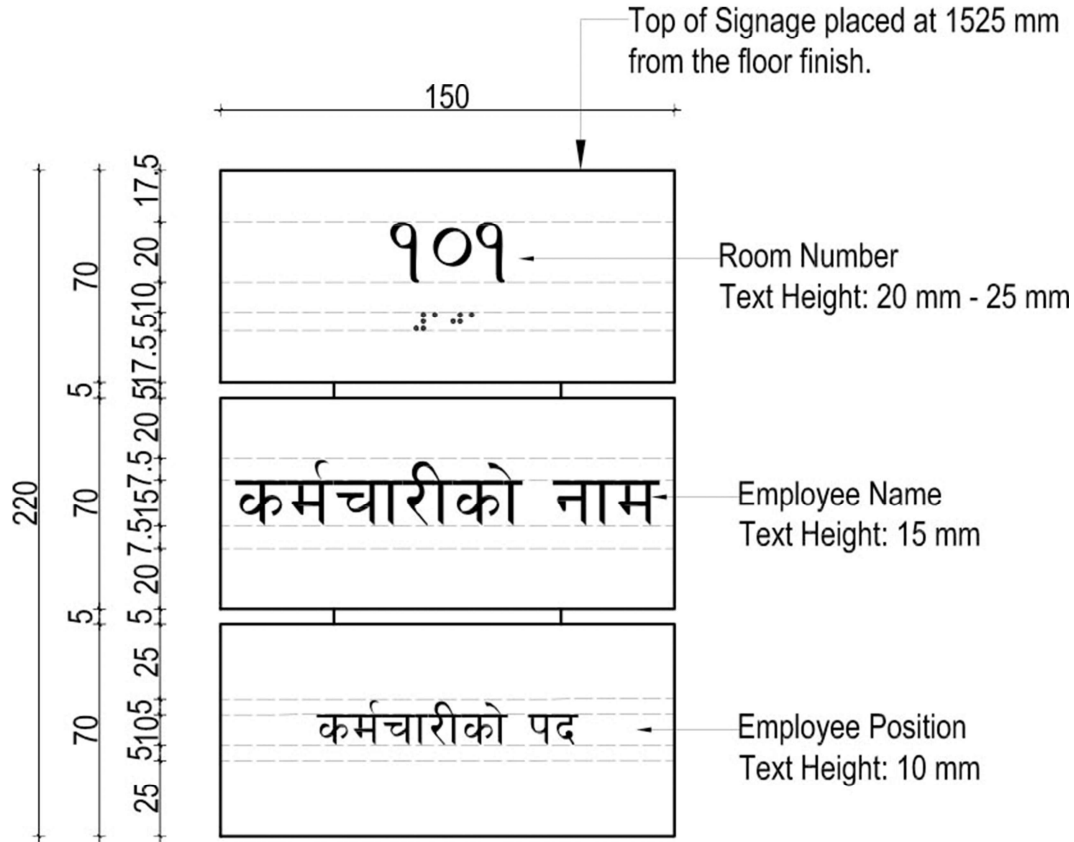
Placement:
Top of Signage placed at 1525 from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be beside a door for all offices. It has room number, employee's name and position.

Please note: signage dimensions can be adjusted as per name and position.



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A8

Suite Room I.D.

Artwork Dimensions:
150mm (w) x 210mm (h)

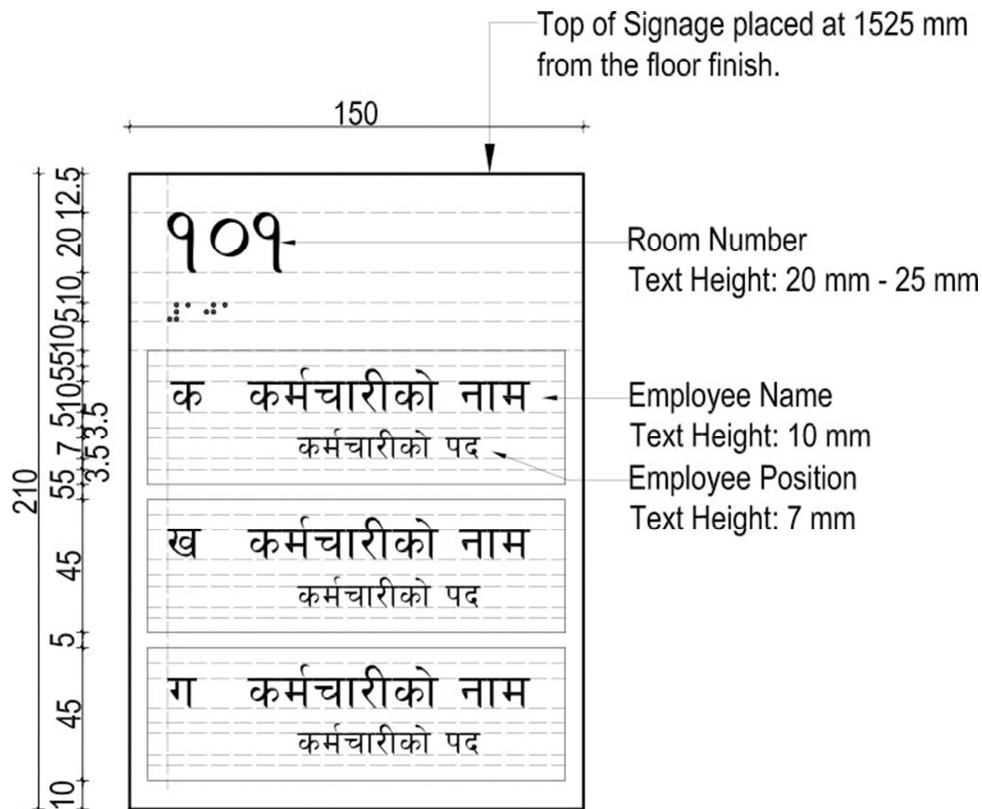
Placement:
Top of Signage placed at 1525 mm from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be beside a door for all suite type offices. It has room number, employee's names and positions.

Please note: signage dimensions can be adjusted as per name and position.



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A9

Stair

Artwork Dimensions:
150mm (w) x 200mm (h)

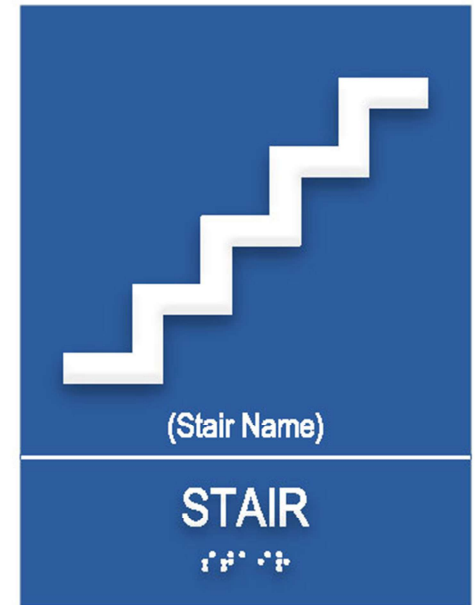
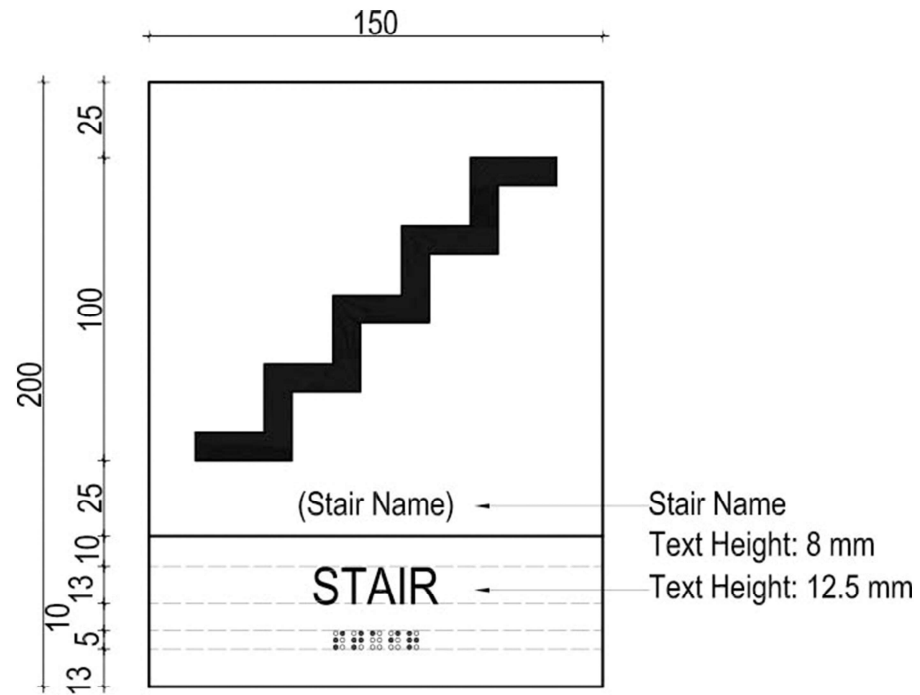
Placement:
Top of Signage placed at 1525 from floor finish.

Font Style:
Arial

General Notes:

This signage is to be used beside a door for all staircases.

Please note: Braille is required for stair location.



Internal Signage Templates

Signage Type A10

Restroom

Artwork Dimensions:
150mm (w) x 200mm (h)

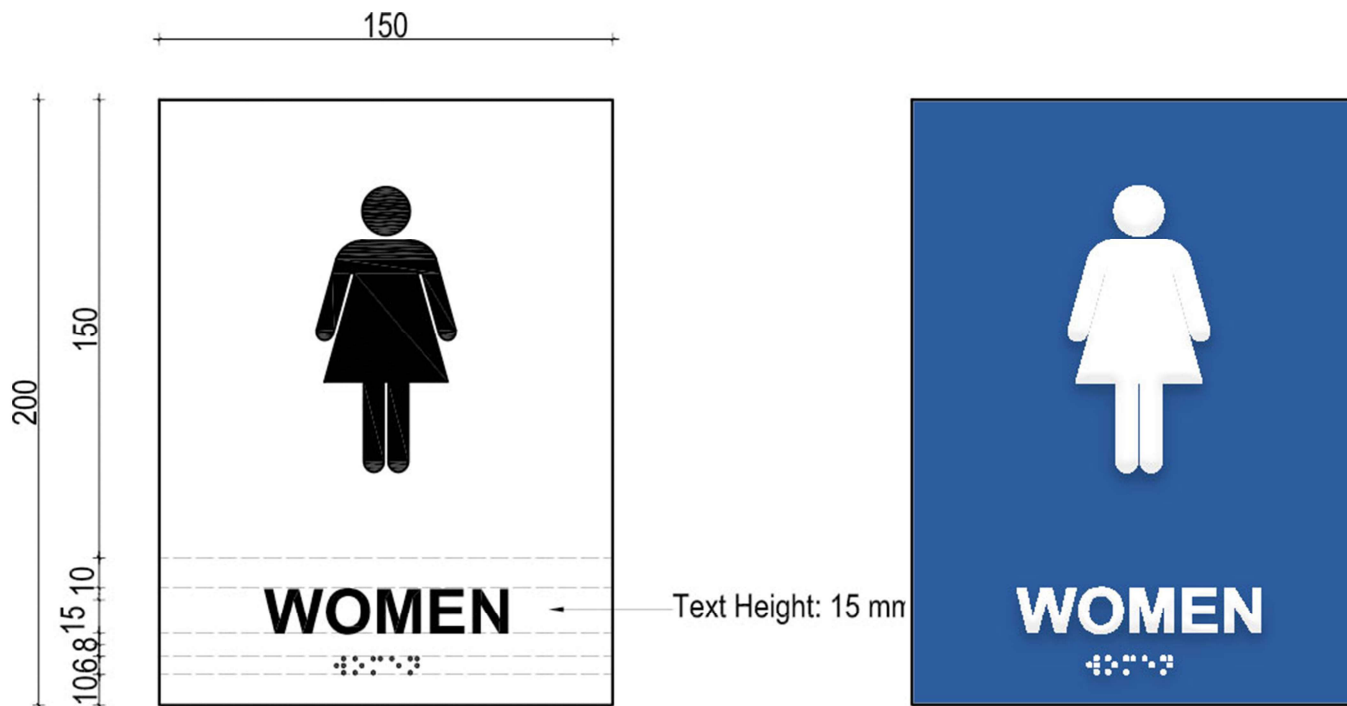
Placement:
Top of Signage placed at 1525 from floor finish.

Font Style:
Arial

General Notes:

This signage is to be used beside or on door of restroom.

Please note: Signage placement can vary depending on its location. Braille is required for restroom location.



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A11

Stairwell

Artwork Dimensions:
200mm (w) x 125mm (h)

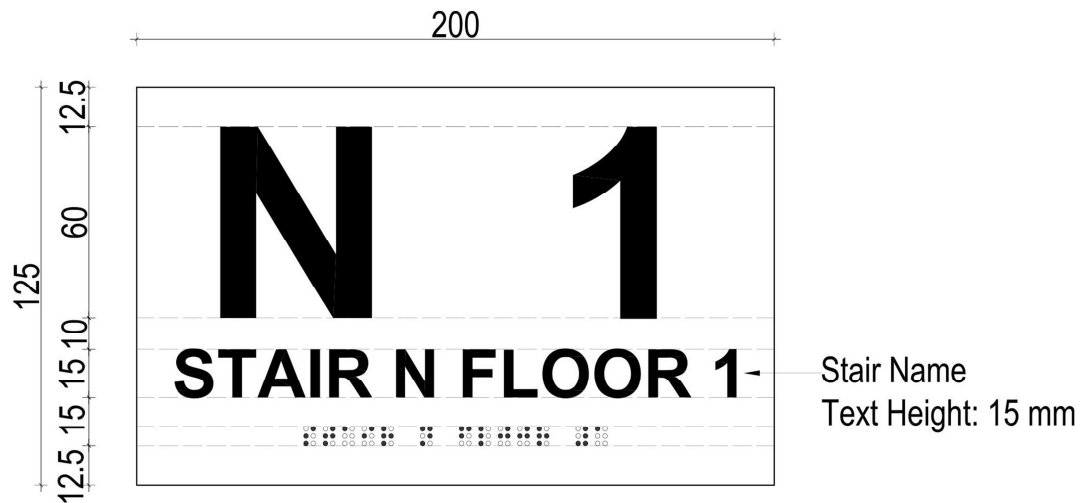
Placement:
Top of Signage placed at 1525 from floor
finish.

Font Style:
Arial

General Notes:

This signage is to be placed inside
stairwell at each exit point on each floor.
Language shall be modified as needed to
communicate building layout.

*Please note: Signage dimension can vary
depending on its content. Braille is
required for stairwell location.*



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

285

Signage Type A12

Floor

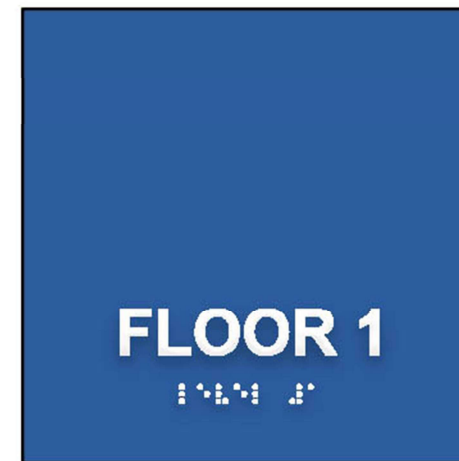
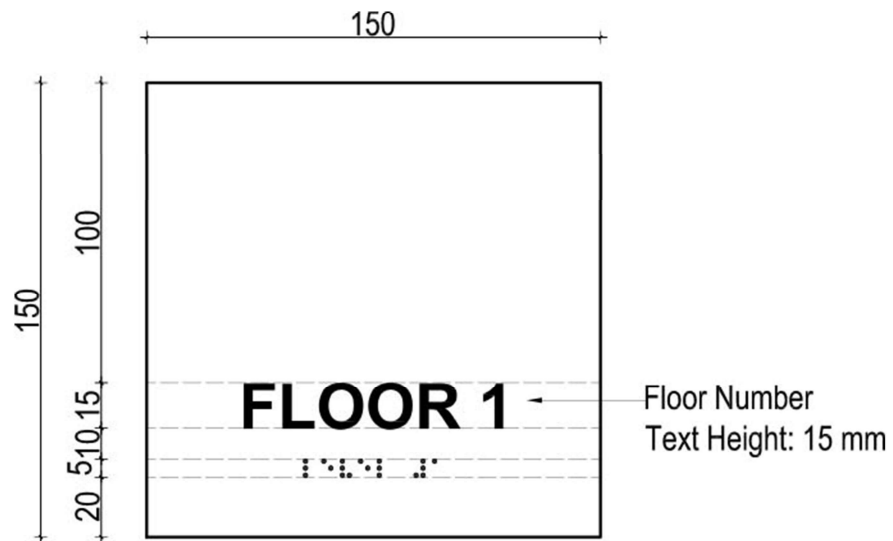
Artwork Dimensions:
150mm (w) x 150mm (h)

Placement:
Top of Signage placed at 1525 from floor
finish.

Font Style:
Arial

General Notes:

This signage is to be used in stairwells to
indicate the level/ floor you are on. The
sign is wall mounted.



*Please note: Floor can be used instead of
Level.*

Internal Signage Templates

Signage Type A13

Exit

Artwork Dimensions:

Type A: 150mm (w) x 150mm (h)

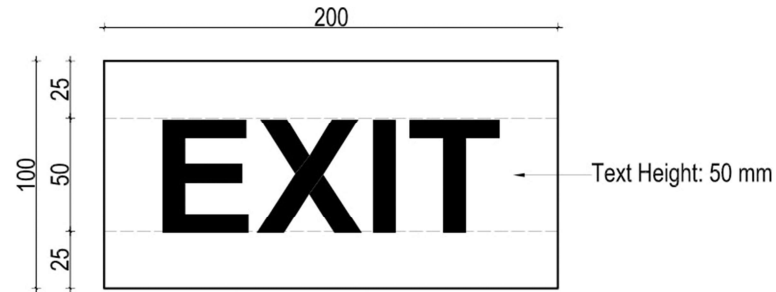
Type B: 200mm (w) x 100mm (h)

Placement:

Top of Signage placed at 1525 from floor

Font Style:

Arial



Type A

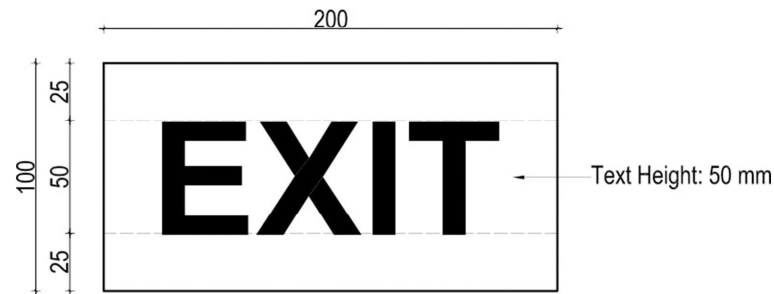
General Notes:

This signage must be clearly visible to persons approaching the exit.

It is to be used on, above or adjacent to each door providing direct egress from a storey to an enclosed or external stairway, passageway or ramp serving as a required exit; and on, above or adjacent to a door to an external access balcony leading to a required exit.

It is to be used above or adjacent to each door from an enclosed stairway, passageway or ramp at every level of discharge to a road or open space.

Please Note: Emergency Exit signage must be red in color and Fire Exit signage must be green in color.



Type B

Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A14

Directories

Artwork Dimensions:
900mm (w) x 990mm (h)

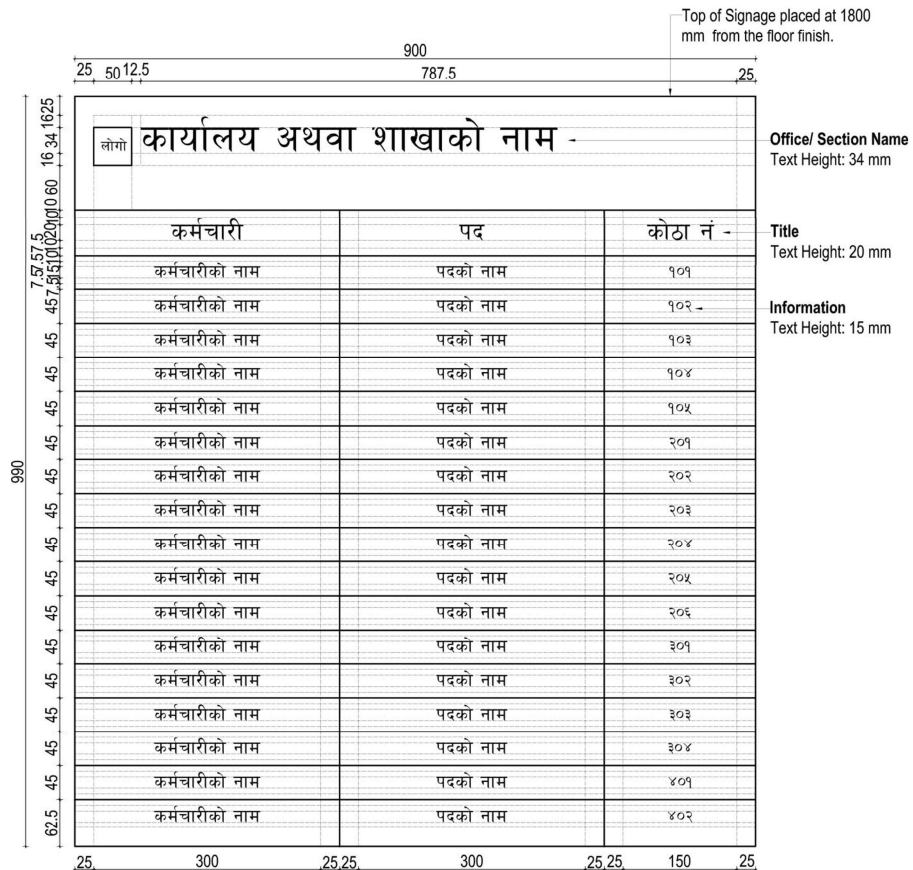
Placement:
Top of Signage placed at 1800mm from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be used in entryways of the buildings (any building over 1,000 sqm). Directories will also be placed by any secondary entrances widely used by the public. The directories are intended to show a building plan, department names, staff names, and room numbers.

Please Note: Signage dimensions can vary as per requirement.



कार्यालय अथवा शाखाको नाम		
कर्मचारी	पद	कोठा नं
कर्मचारीको नाम	पदको नाम	१०१
कर्मचारीको नाम	पदको नाम	१०२
कर्मचारीको नाम	पदको नाम	१०३
कर्मचारीको नाम	पदको नाम	१०४
कर्मचारीको नाम	पदको नाम	१०५
कर्मचारीको नाम	पदको नाम	२०१
कर्मचारीको नाम	पदको नाम	२०२
कर्मचारीको नाम	पदको नाम	२०३
कर्मचारीको नाम	पदको नाम	२०४
कर्मचारीको नाम	पदको नाम	२०५
कर्मचारीको नाम	पदको नाम	२०६
कर्मचारीको नाम	पदको नाम	३०१
कर्मचारीको नाम	पदको नाम	३०२
कर्मचारीको नाम	पदको नाम	३०३
कर्मचारीको नाम	पदको नाम	३०४
कर्मचारीको नाम	पदको नाम	४०१
कर्मचारीको नाम	पदको नाम	४०२

Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A15

Directories

Artwork Dimensions:
450mm (w) x 800mm (h)

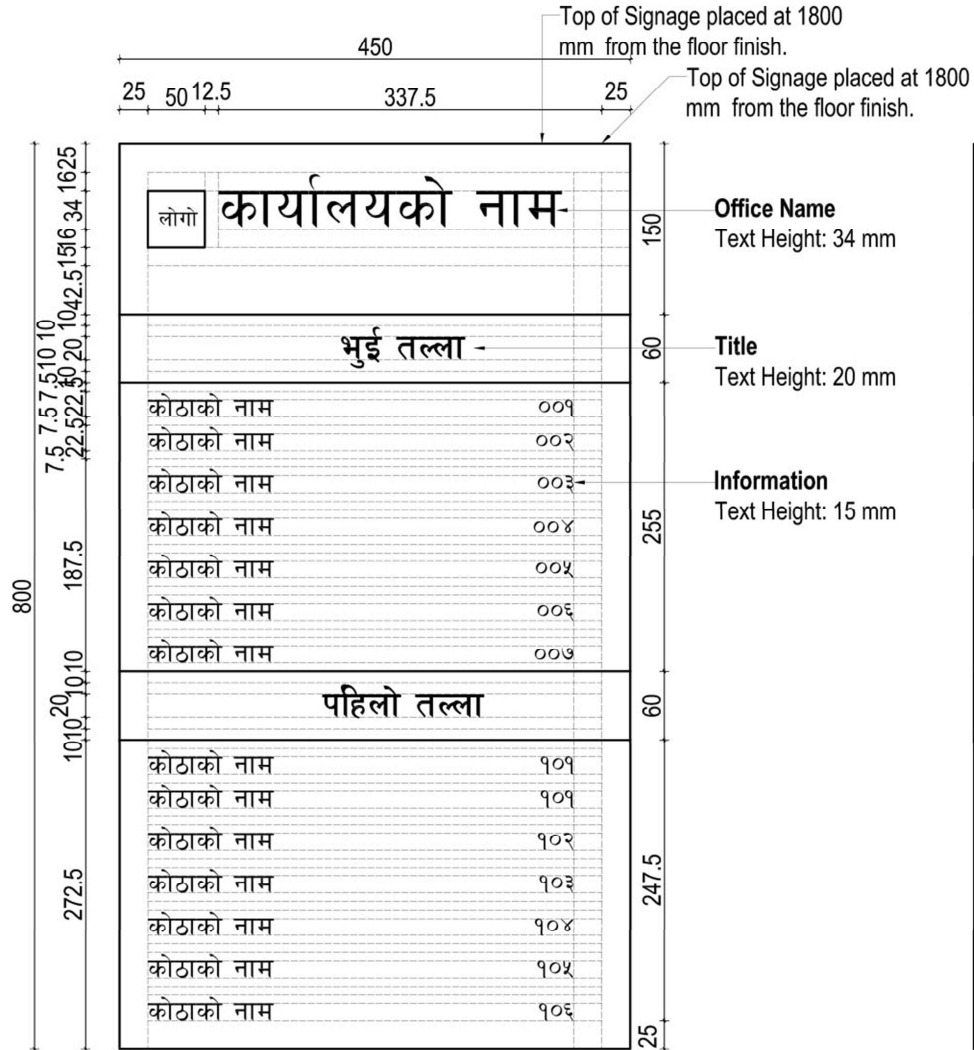
Placement:
Top of Signage placed at 1800mm from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be used in entryways of the buildings (any building over 1,000 sqm). Directories will also be placed by any secondary entrances widely used by the public. The directories are intended to show building name, room names, and room numbers of each floor.

Please Note: Signage dimensions can vary as per requirement.



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A16

Directional

Artwork Dimensions:
500mm (w) x 475mm (h)

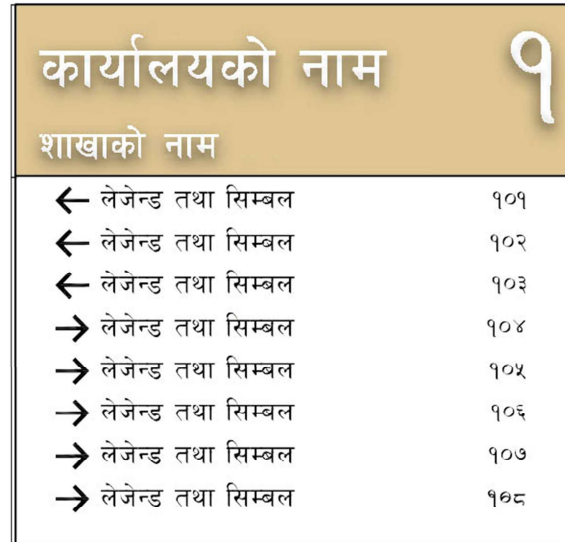
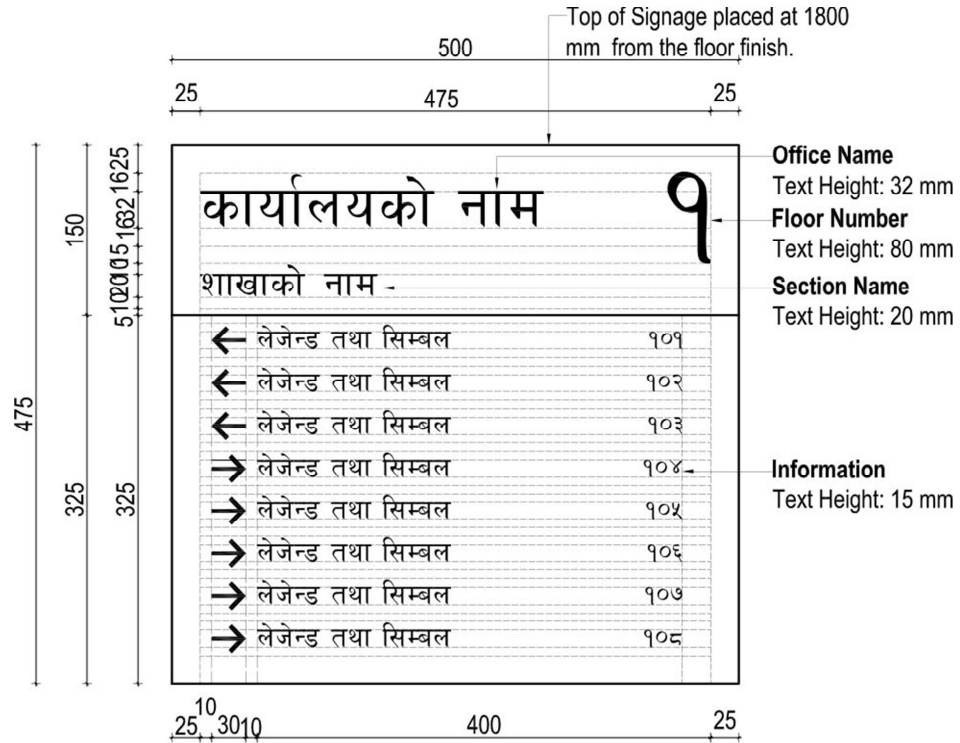
Placement:
Top of Signage placed at 1800mm from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be used at lifts/stairwells and main entrances to identify the full range of destinations in the building and the floor the user is on.

Please Note: Signage dimensions can vary as per requirement.



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A17

Building Plan

Artwork Dimensions:
500mm (w) x 400mm (h)

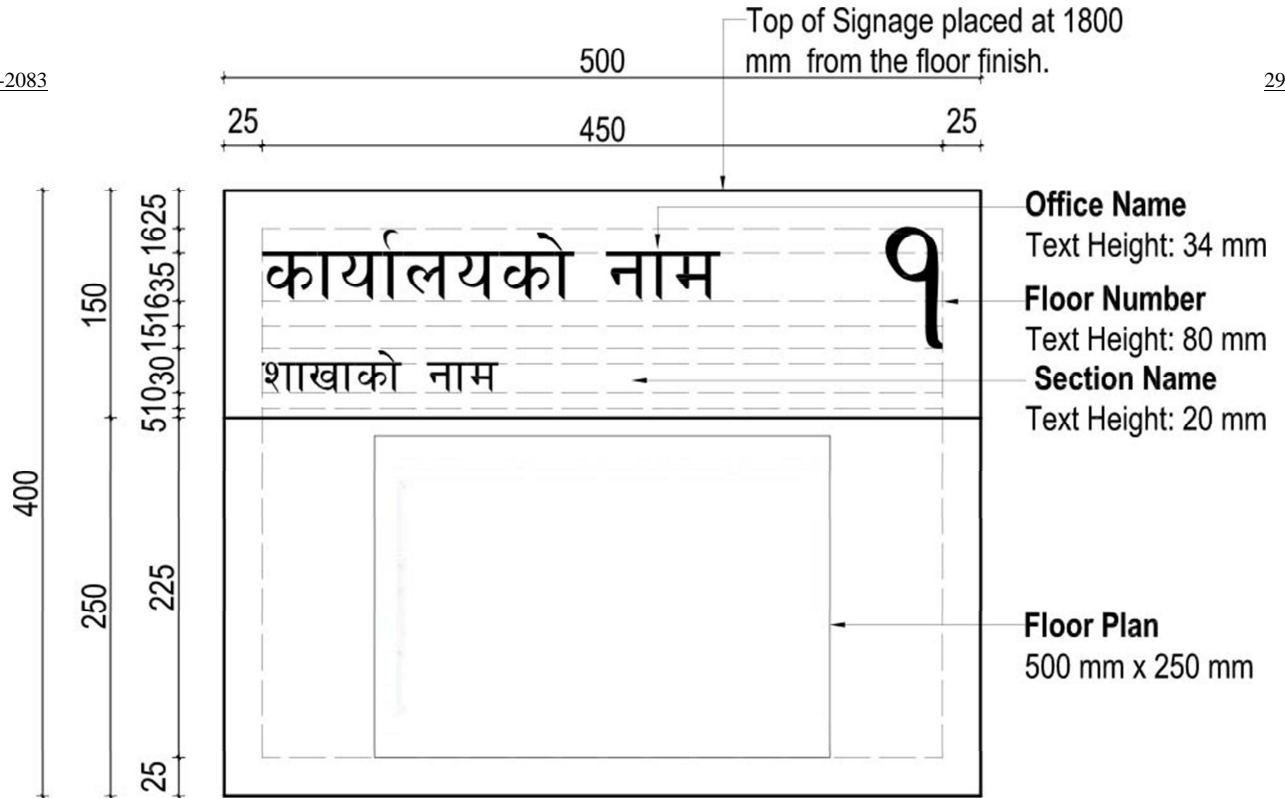
Placement:
Top of Signage placed at 1800mm from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be used at key orientation points and main entrances. This sign is primarily used to show a flat map of a singular floor. It can also be used alongside Sign Type's A15 and A16.

Please Note: Signage dimensions can vary as per requirement.



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A18

Evacuation Plan

Artwork Dimensions:
450mm (w) x 555mm (h)

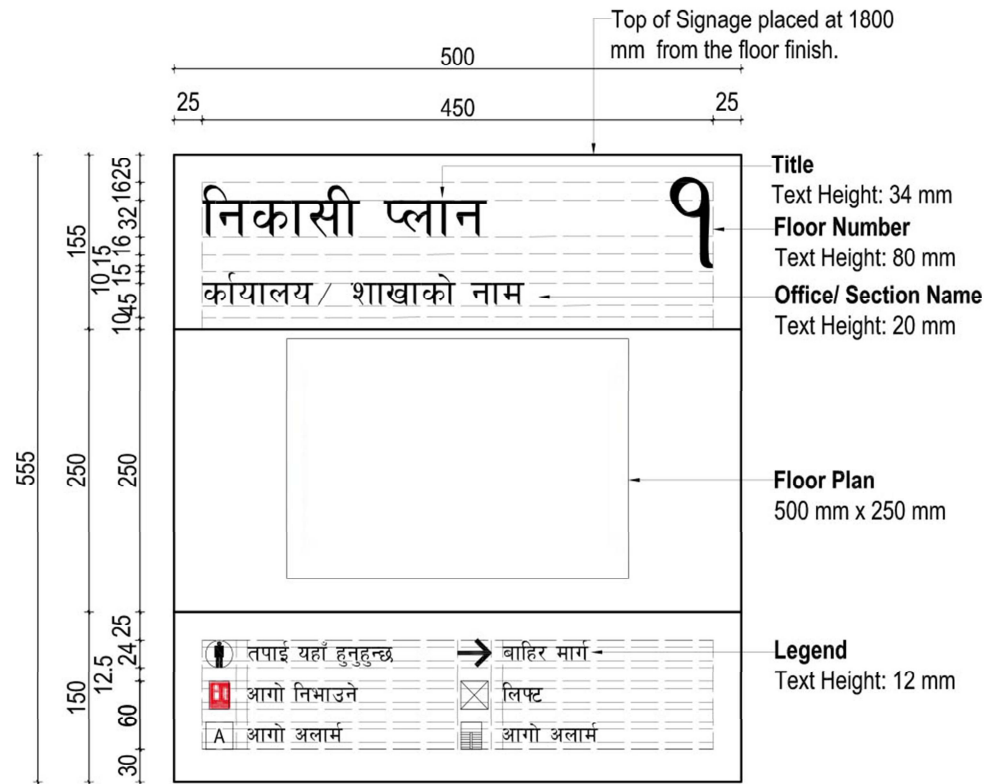
Placement:
Top of Signage placed at 1800mm from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be placed plentifully throughout every building, mainly at key orientation points and main entrances.. At a minimum, one will be posted at every entrance to every floor in all buildings.

Please Note: Signage dimensions can vary as per requirement.



Internal Signage Templates

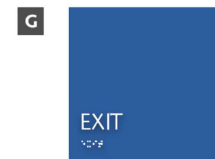
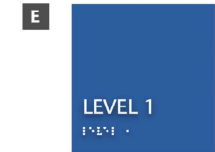
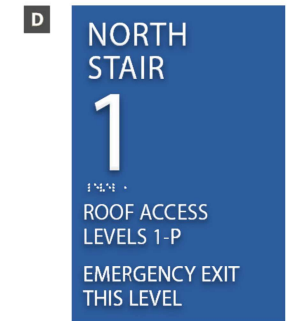
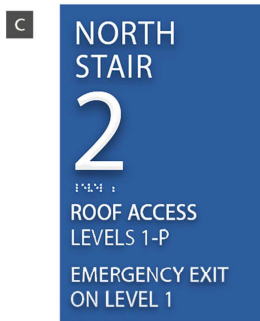
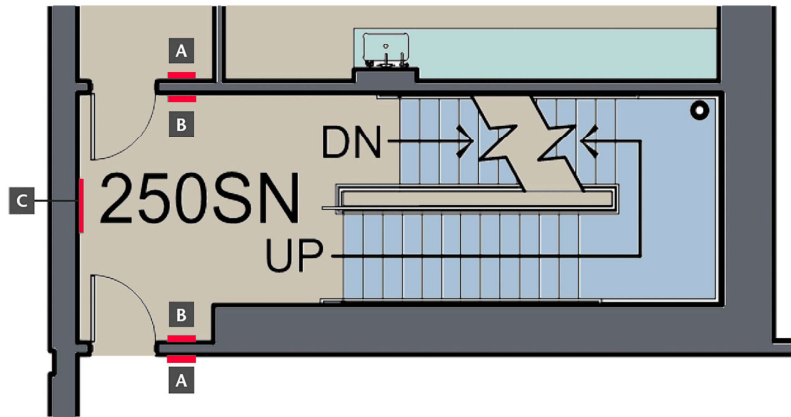
Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A19

Stair Signage Locations

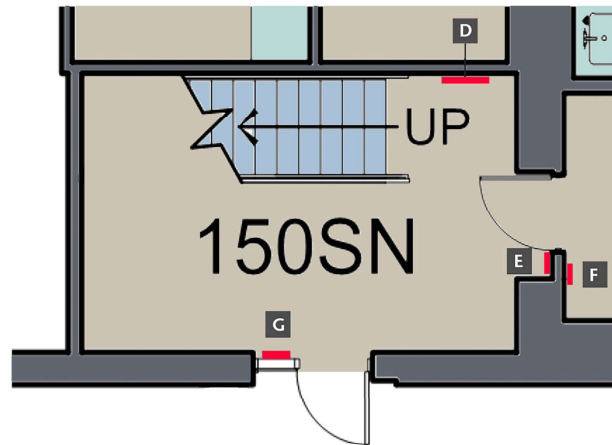
Placement:
Top of Signage placed at 1800mm from floor finish.

Font Style:
Arial



General Notes:

The staircase plans have all required informational signages at various locations.



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A20-1

Citizen's Charter

Artwork Dimensions:
4500mm (w) x 1500mm (h)

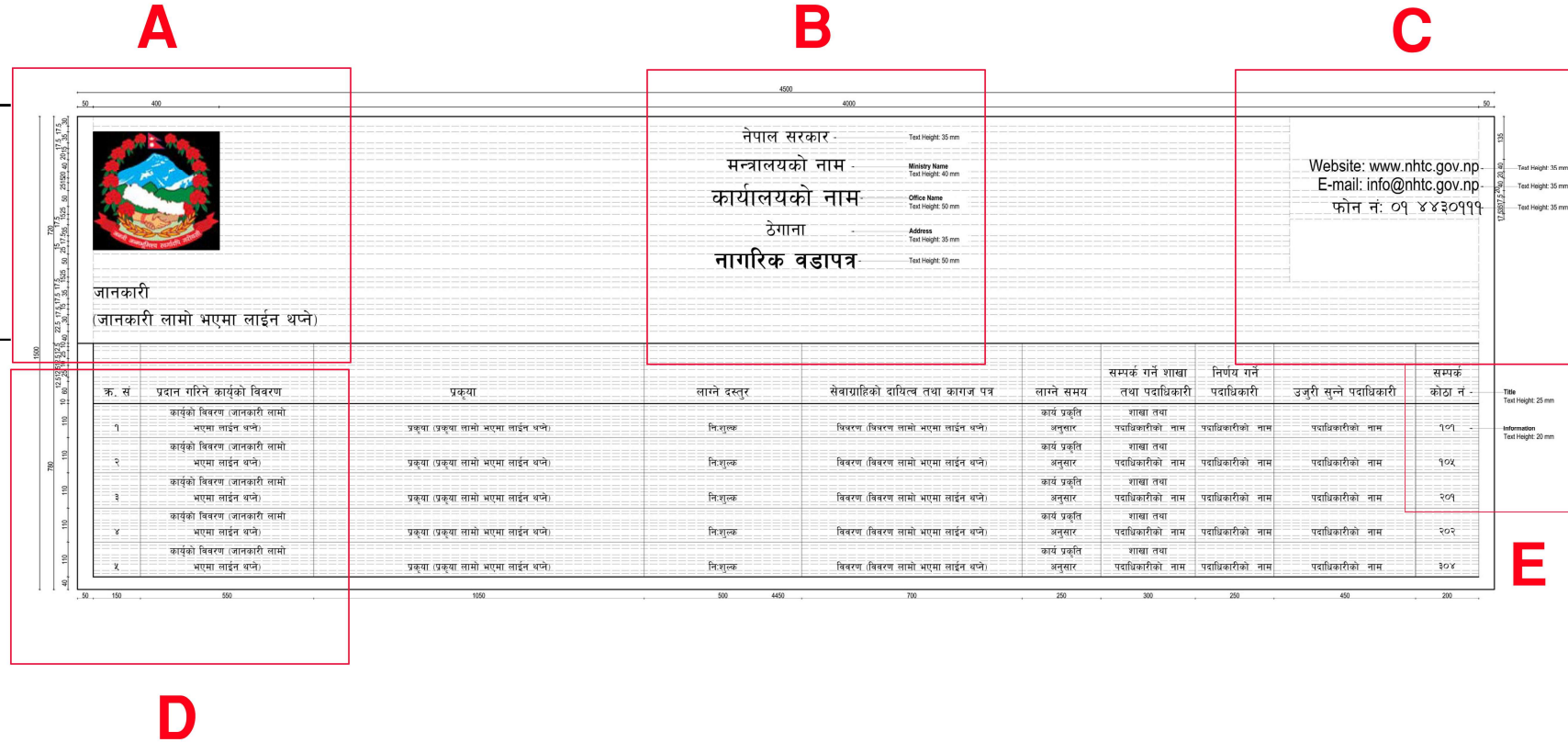
Placement:
Top of Signage placed at 1800mm from floor finish.

Font Style:
Preeti
Arial

General Notes:

This signage is to be placed at main entrance.

Please Note: Signage dimensions and contents can vary as per requirement.



Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type A20-2

Citizen's Charter

Artwork Dimensions:
4500mm (w) x 1500mm (h)

Placement:
Top of Signage placed at 1800mm from floor finish.

Font Style:
Preeti
Arial

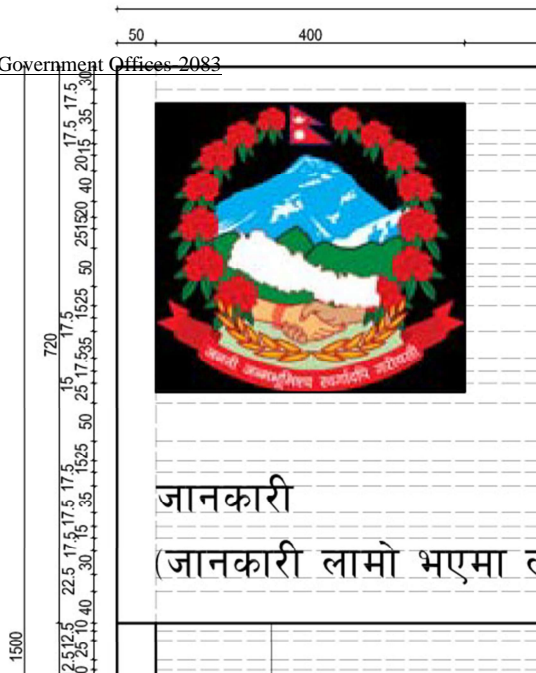


Fig. A

General Notes:

This signage is to be placed at main entrance.

Please Note: Signage dimensions and contents can vary as per requirement.



Fig. C

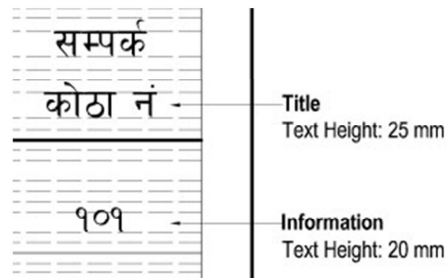


Fig. E

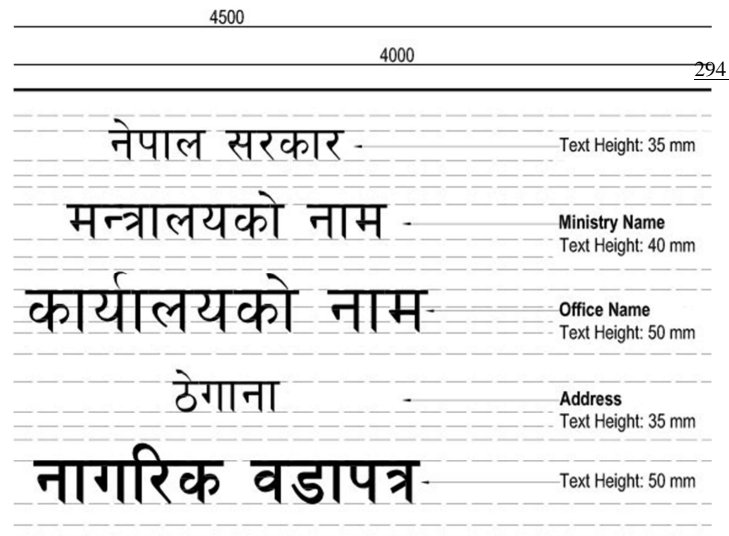


Fig. B

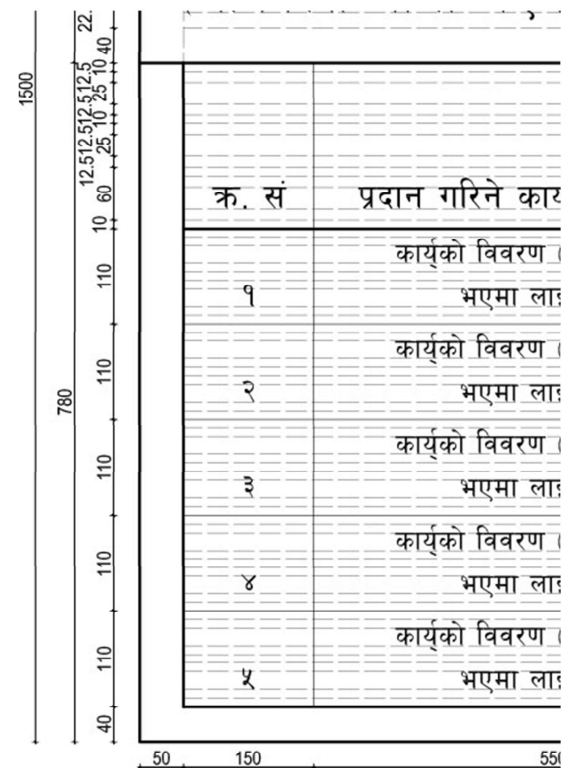


Fig. D

Internal Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

295

Signage Type A20-3

Citizen's Charter

Artwork Dimensions:
4500mm (w) x 1500mm (h)


Placement:
Top of Signage placed at 1800mm from
floor finish.

Font Style:
Preeti
Arial

General Notes:

This signage is to be placed at main
entrance.

*Please Note: Signage dimensions and
contents can vary as per requirement.*



नेपाल सरकार
मन्त्रालयको नाम
कार्यालयको नाम
ठेगाना
नागरिक वडापत्र

Website: www.nhtc.gov.np
E-mail: info@nhtc.gov.np
फोन नं: ०१ ४४३०१११





जानकारी
(जानकारी लामो भएमा लाईन थप्ने)

क्र. सं	प्रदान गरिने कार्यको विवरण	प्रकृत्या	लाग्ने दस्तुर	सेवाग्राहिको दायित्व तथा कागज पत्र	लाग्ने समय	सम्पर्क गर्ने शाखा तथा पदाधिकारी	निर्णय गर्ने पदाधिकारी	उजुरी सुन्ने पदाधिकारी	सम्पर्क कोठा नं
१	कार्यको विवरण (जानकारी लामो भएमा लाईन थप्ने)	प्रकृत्या (प्रकृत्या लामो भएमा लाईन थप्ने)	नि:शुल्क	विवरण (विवरण लामो भएमा लाईन थप्ने)	कार्य प्रकृत अनुसार	शाखा तथा पदाधिकारीको नाम	पदाधिकारीको नाम	पदाधिकारीको नाम	१०१
२	कार्यको विवरण (जानकारी लामो भएमा लाईन थप्ने)	प्रकृत्या (प्रकृत्या लामो भएमा लाईन थप्ने)	नि:शुल्क	विवरण (विवरण लामो भएमा लाईन थप्ने)	कार्य प्रकृत अनुसार	शाखा तथा पदाधिकारीको नाम	पदाधिकारीको नाम	पदाधिकारीको नाम	१०५
३	कार्यको विवरण (जानकारी लामो भएमा लाईन थप्ने)	प्रकृत्या (प्रकृत्या लामो भएमा लाईन थप्ने)	नि:शुल्क	विवरण (विवरण लामो भएमा लाईन थप्ने)	कार्य प्रकृत अनुसार	शाखा तथा पदाधिकारीको नाम	पदाधिकारीको नाम	पदाधिकारीको नाम	२०१
४	कार्यको विवरण (जानकारी लामो भएमा लाईन थप्ने)	प्रकृत्या (प्रकृत्या लामो भएमा लाईन थप्ने)	नि:शुल्क	विवरण (विवरण लामो भएमा लाईन थप्ने)	कार्य प्रकृत अनुसार	शाखा तथा पदाधिकारीको नाम	पदाधिकारीको नाम	पदाधिकारीको नाम	२०२
५	कार्यको विवरण (जानकारी लामो भएमा लाईन थप्ने)	प्रकृत्या (प्रकृत्या लामो भएमा लाईन थप्ने)	नि:शुल्क	विवरण (विवरण लामो भएमा लाईन थप्ने)	कार्य प्रकृत अनुसार	शाखा तथा पदाधिकारीको नाम	पदाधिकारीको नाम	पदाधिकारीको नाम	२०४

RECOMMENDED LIST FOR INTERNAL SIGNAGE

S. No.	DESCRIPTION	SIGNAGE TYPE	MATERIAL	COLOR	
				FOREGROUND (Text, Pictures)	BACKGROUND
1	Room ID	A1, A2, A3, A4, A5 & A6, A7, A8	Acrylic	White	Blue
			Wooden	White	Wooden Texture
2	Stair	A9,	Acrylic, Metal	White	Blue
3	Restroom	A10	Acrylic, Metal	White	Blue
4	Stairwell	A11	Acrylic, Metal	White	Blue
5	Floor	A12	Acrylic, Metal	White	Blue
6	Exit	A13	Acrylic, Metal	White	Green
			Acrylic, Metal, Black lit and illuminated	White	Red
7	Directories	A14	Acrylic	Red	White
8	Directories	A15	Acrylic	Red	White
9	Directional	A16	Acrylic	Red	White
10	Building Plan	A17	Acrylic	Red	White
11	Evacuation Plan	A18	Acrylic	Red	White
12	Stair Signage Location	A19	Acrylic	White	Blue
13	Citizen's Charter	A20	Acrylic	Red/ Blue	White
14	Information Officer	A21	Acrylic	Red/ Blue	White

Legends:

White:	
Blue:	
Red:	
Green:	

EXTERNAL SIGNAGE TEMPLATES

External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E2

Wall Mounted Signage

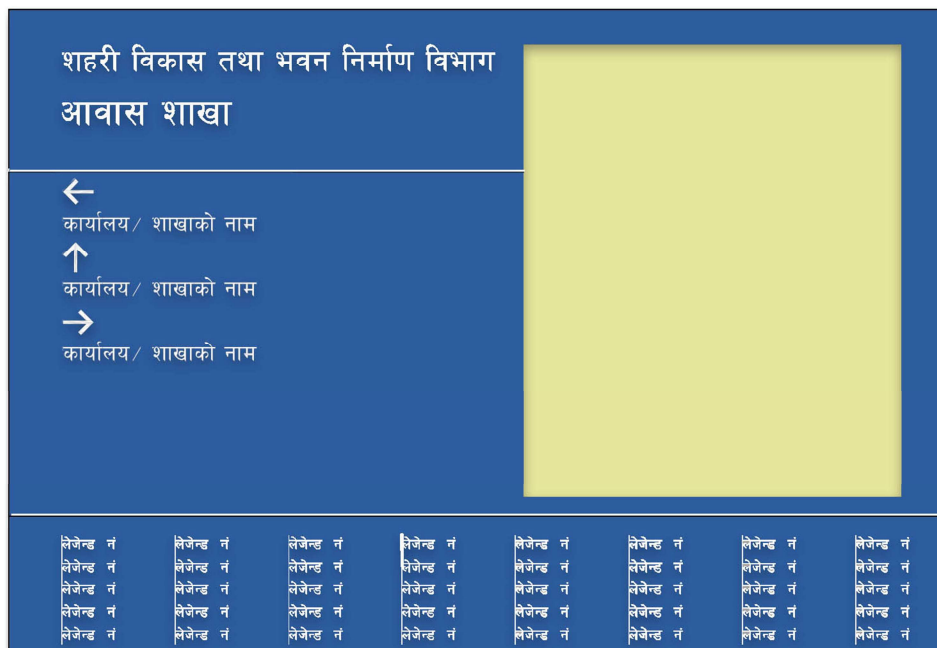
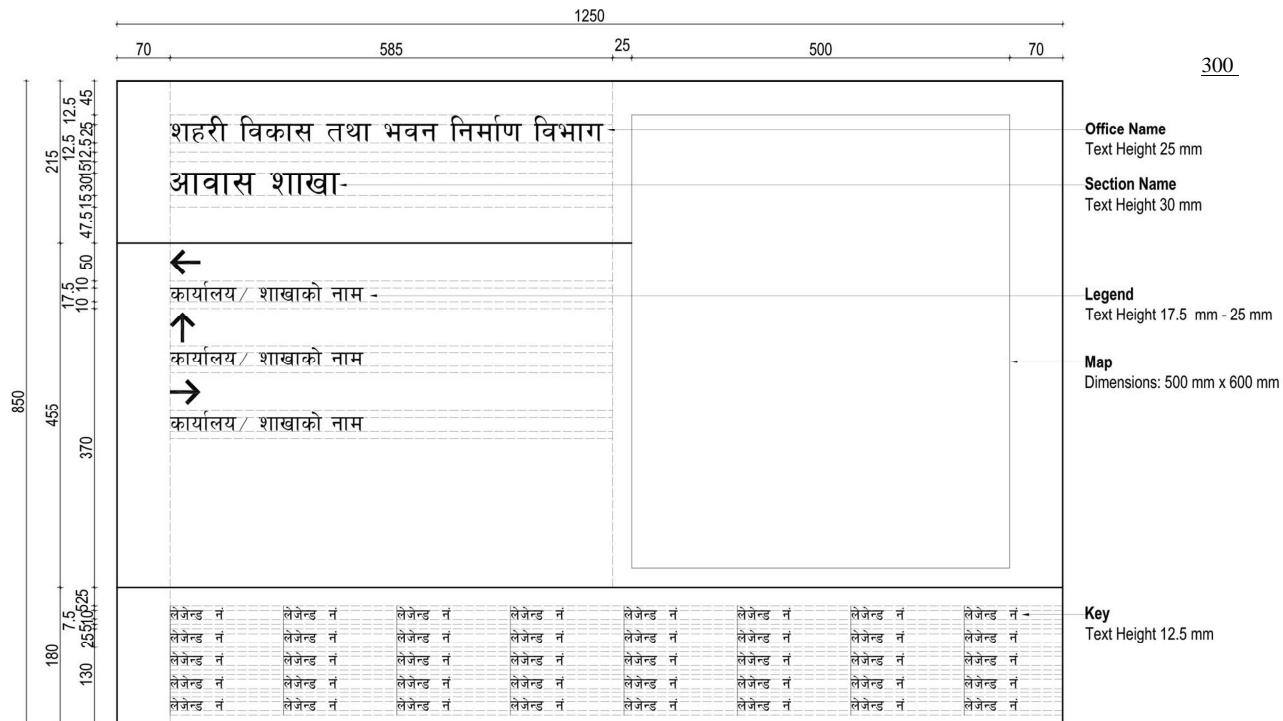
Artwork Dimensions:
120mm (w) x 850mm (h)

Placement:
Top of the Signage placed at 2200mm from GL.

Font Style:
Preeti

General Notes:

This signage is wall mounted and to be used at key orientation points along the pedestrian routes near the main entrance, on the approach to the institution. This includes directional content, and a map of the full Institution area.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E3

Vehicular Directional

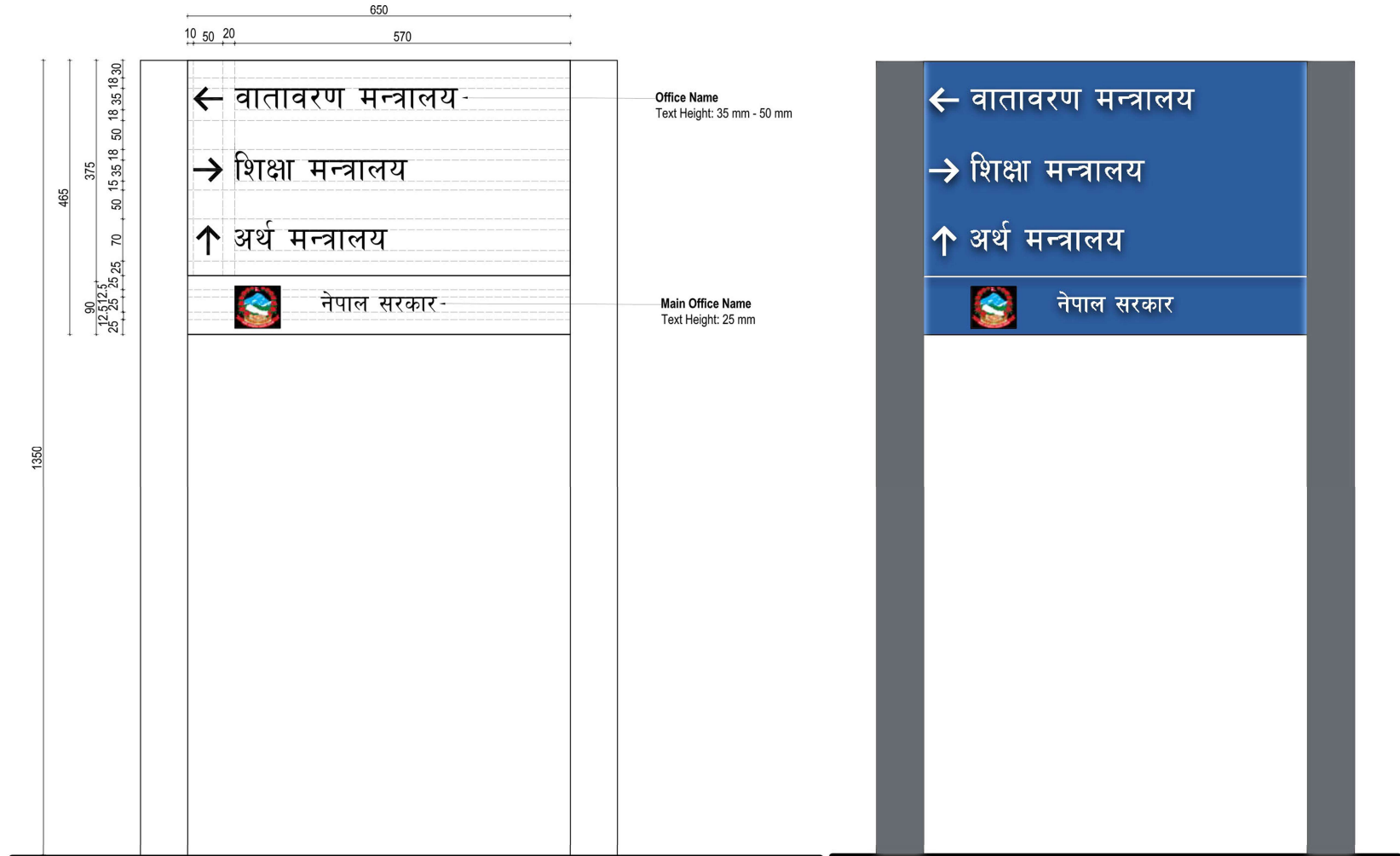
Artwork Dimensions:
650mm (w) x 465mm (h)

Placement:
Top of Signage placed at 1350mm from
GL.

Font Style:
Preeti

General Notes:

This signage gives direction to vehicles to
the locations within the premise.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E4

Vehicular Directional

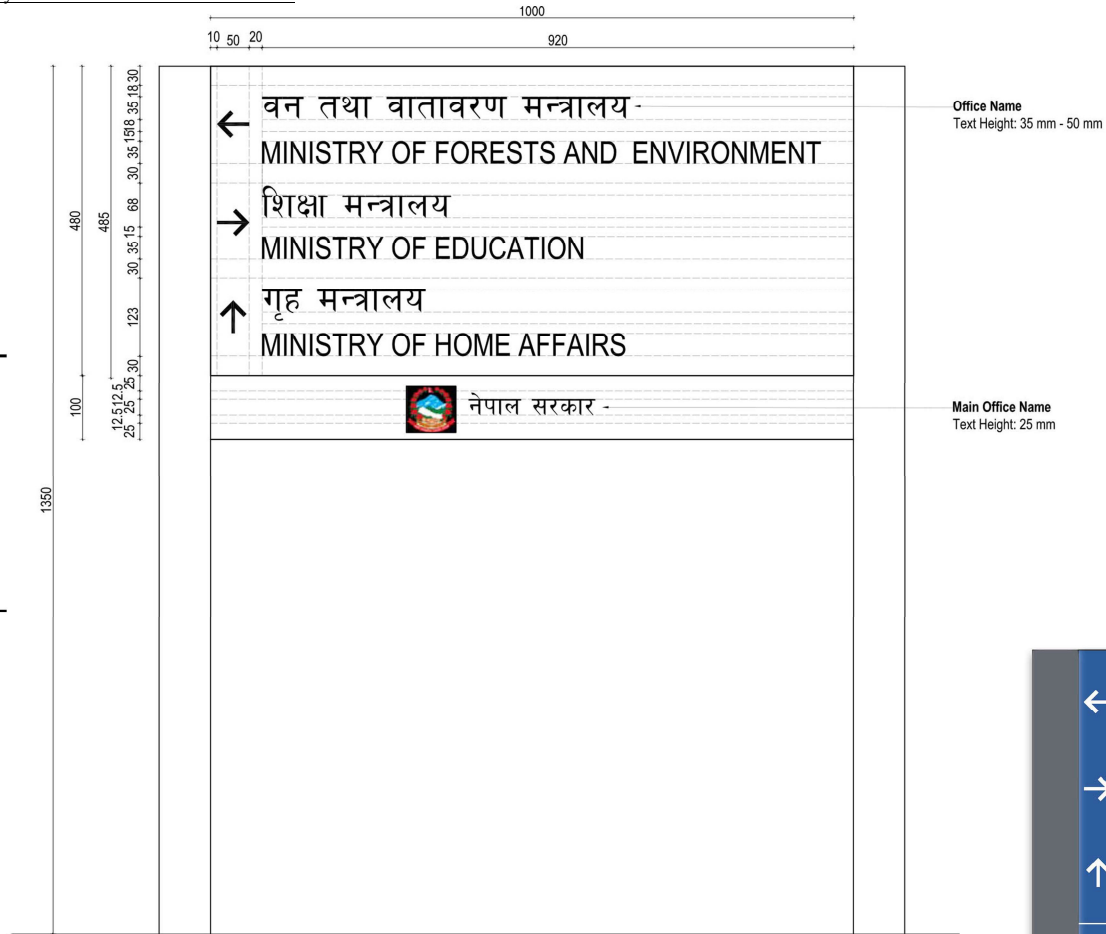
Artwork Dimensions:
100mm (w) x 580mm (h)

Placement:
Top of Signage placed at 1350mm from
GL.

Font Style:
Preeti
Arial

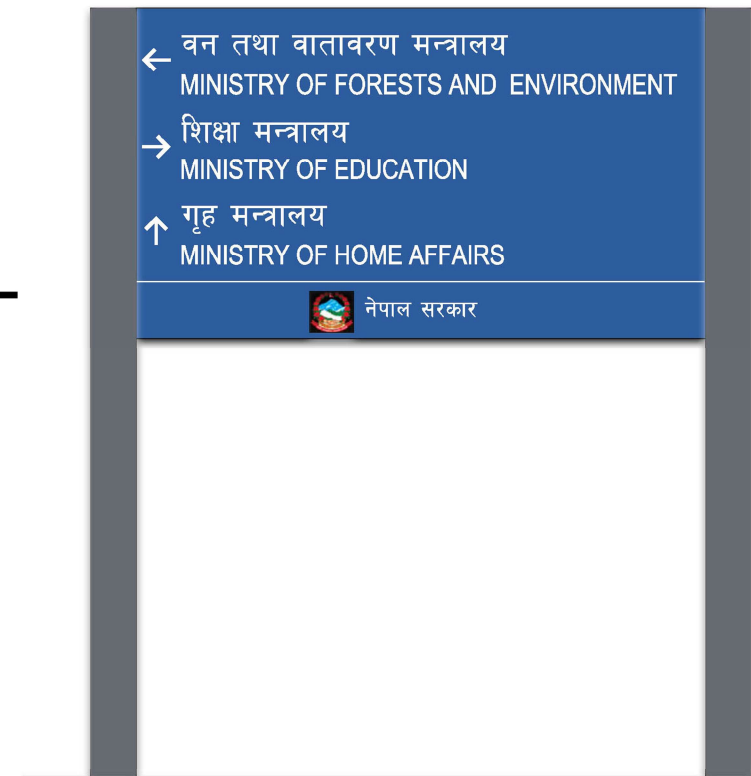
General Notes:

This signage gives direction to vehicles to
the locations within the premise.



Office Name
Text Height: 35 mm - 50 mm

Main Office Name
Text Height: 25 mm



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E5

Pedestrian Directional

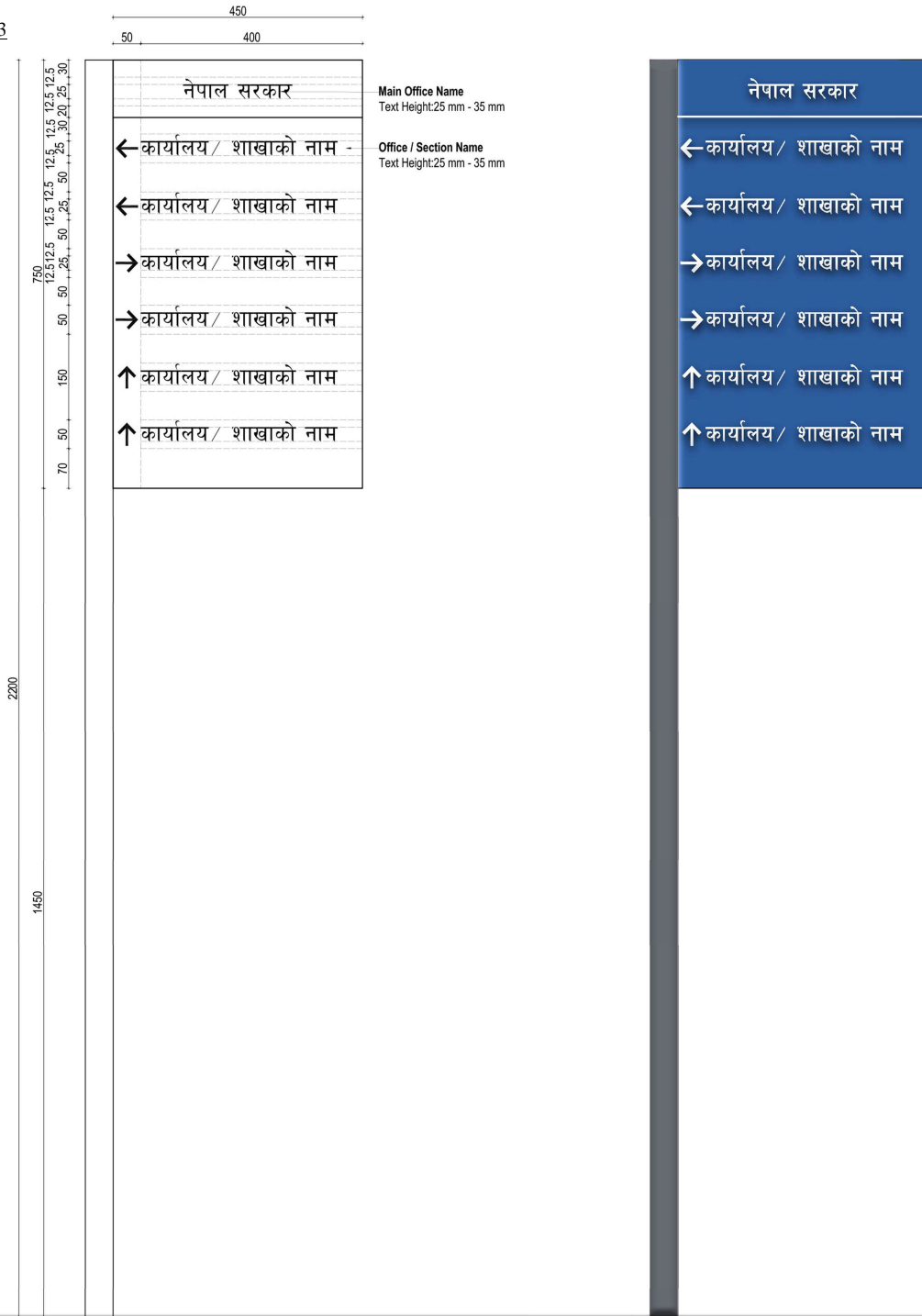
Artwork Dimensions:
450mm (w) x 750mm (h)

Placement:
Top of Signage placed at 2200mm from
GL.

Font Style:
Preeti

General Notes:

This signage gives direction to the pedestrians to the locations within the premise.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E6

Parking Area I.D.

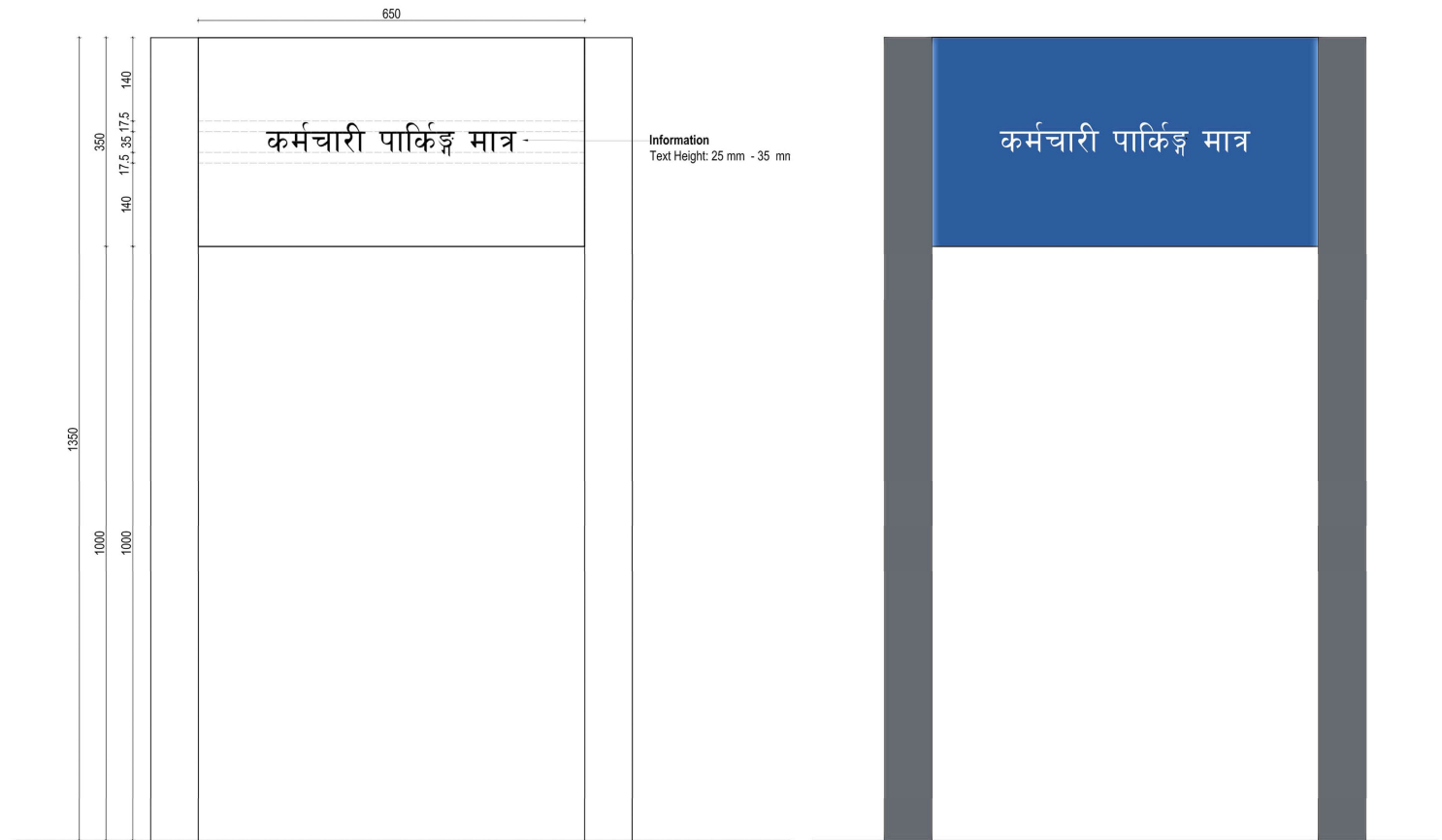
Artwork Dimensions:
650mm (w) x 350mm (h)

Placement:
Top of Signage placed at 1350mm from
GL.

Font Style:
Preeti

General Notes:

This signage is used in parking lot which is
designated for employee only.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E7

Site Information

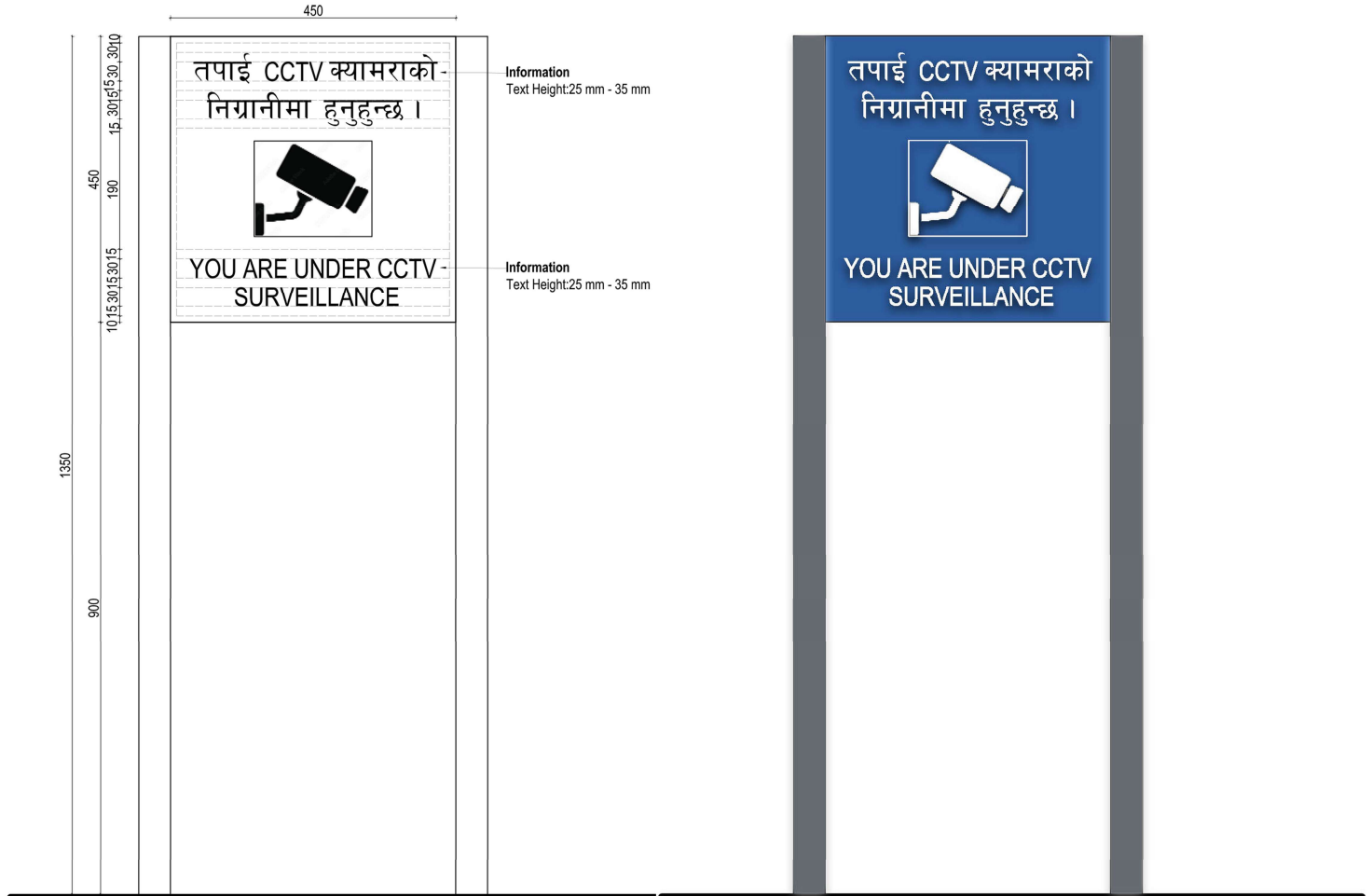
Artwork Dimensions:
450mm (w) x 450mm (h)

Placement:
Top of Signage placed at 1350mm from
GL.

Font Style:
Preeti

General Notes:

This signage is used to notify the presence
of CCTV camera in the permise.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E8

Reserved Parking I.D.

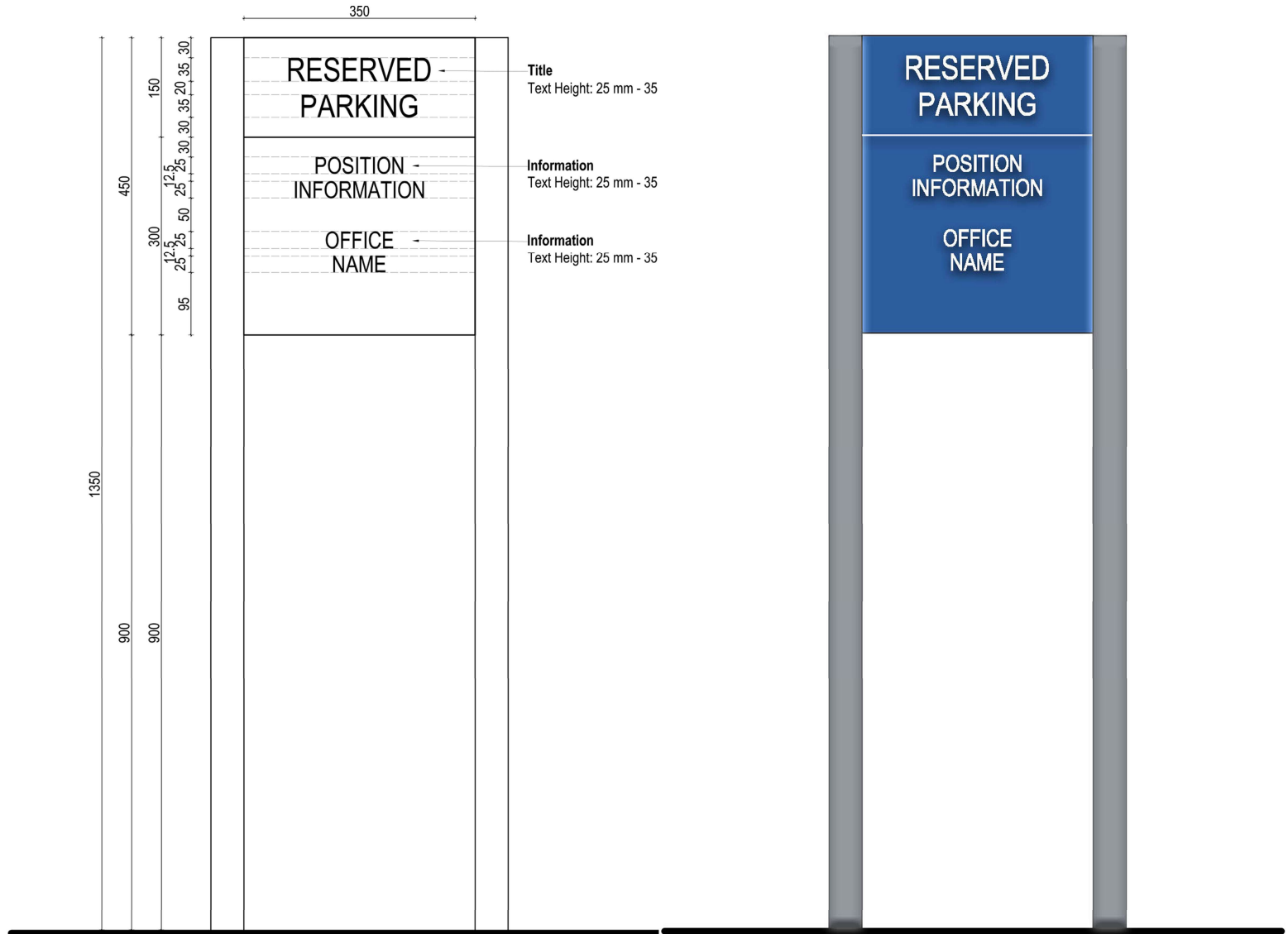
Artwork Dimensions:
350mm (w) x 450mm (h)

Placement:
Top of Signage placed at 1350mm from
GL.

Font Style:
Arial

General Notes:

This signage is used for reserved parking.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

307

Signage Type E9

Reserved Parking I.D.

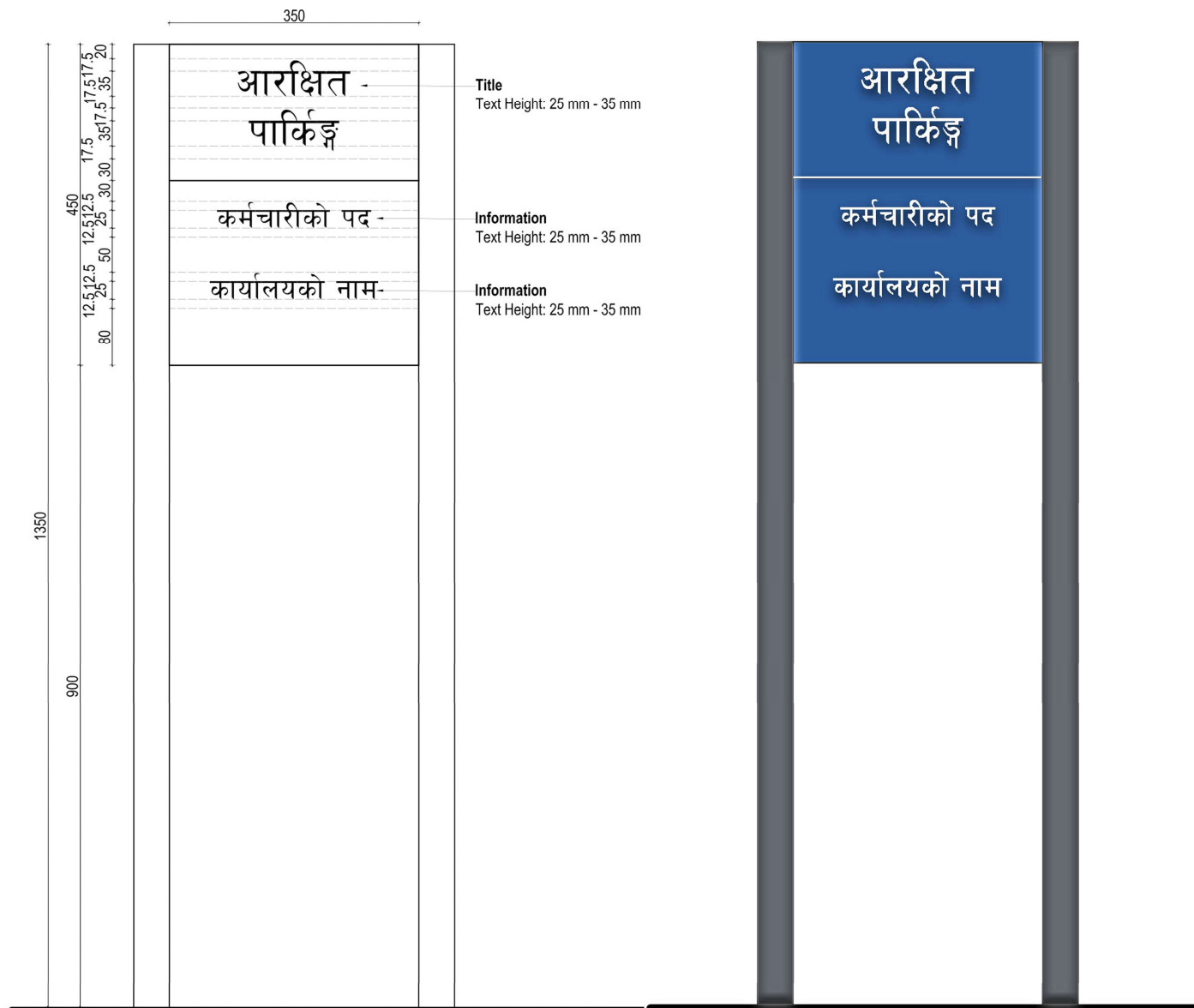
Artwork Dimensions:
350mm (w) x 450mm (h)

Placement:
Top of Signage placed at 1350mm from
GL.

Font Style:
Preeti

General Notes:

This signage is used for reserved parking.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E10

Area I.D.

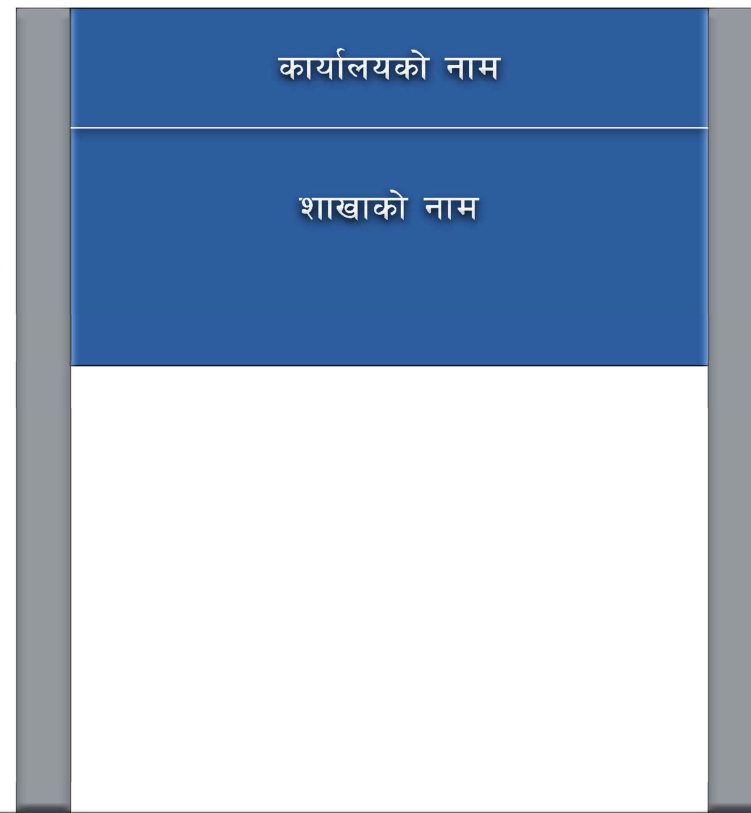
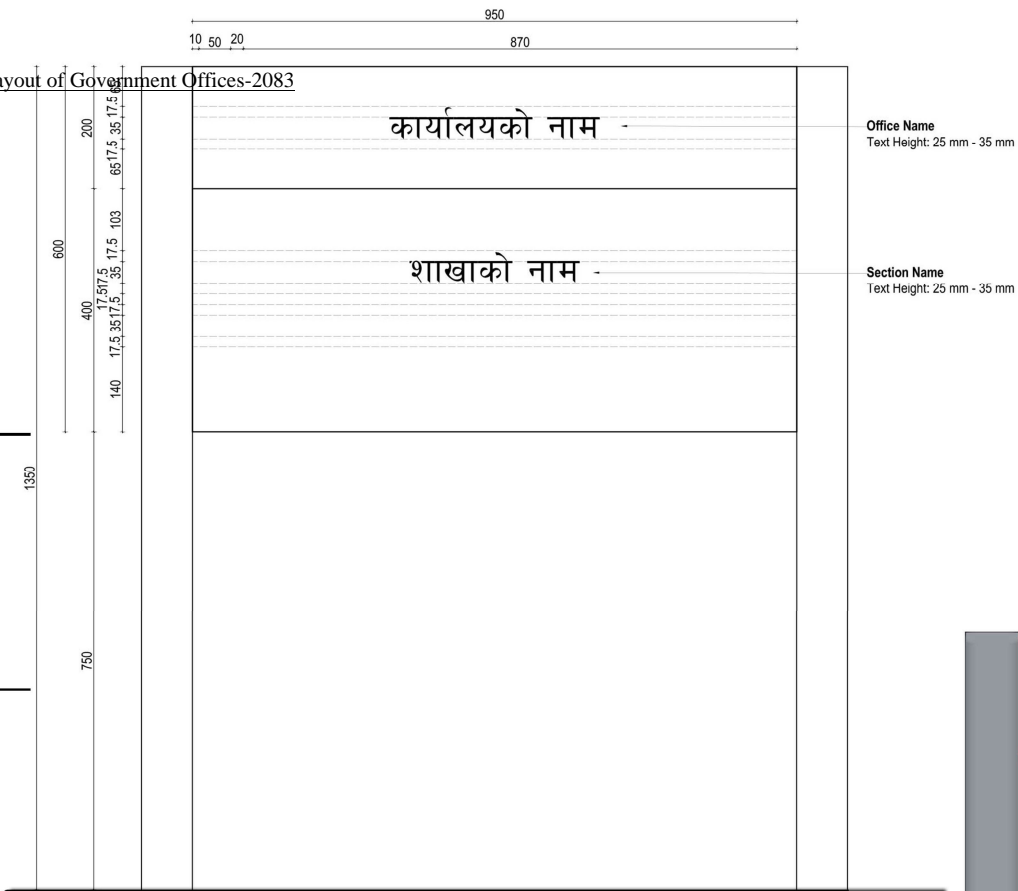
Artwork Dimensions:
950mm (w) x 600mm (h)

Placement:
Top of Signage placed at 1350mm from
GL.

Font Style:
Preeti

General Notes:

This signage is used for area
identification.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E11

Accessibility Signage

Artwork Dimensions:
400mm (w) x 400mm (h)

Placement:
Top of Signage placed at 1050mm from
GL.

Font Style:
Arial

General Notes:

This signage is used at accessible routes
for disables.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E13

Street Signage

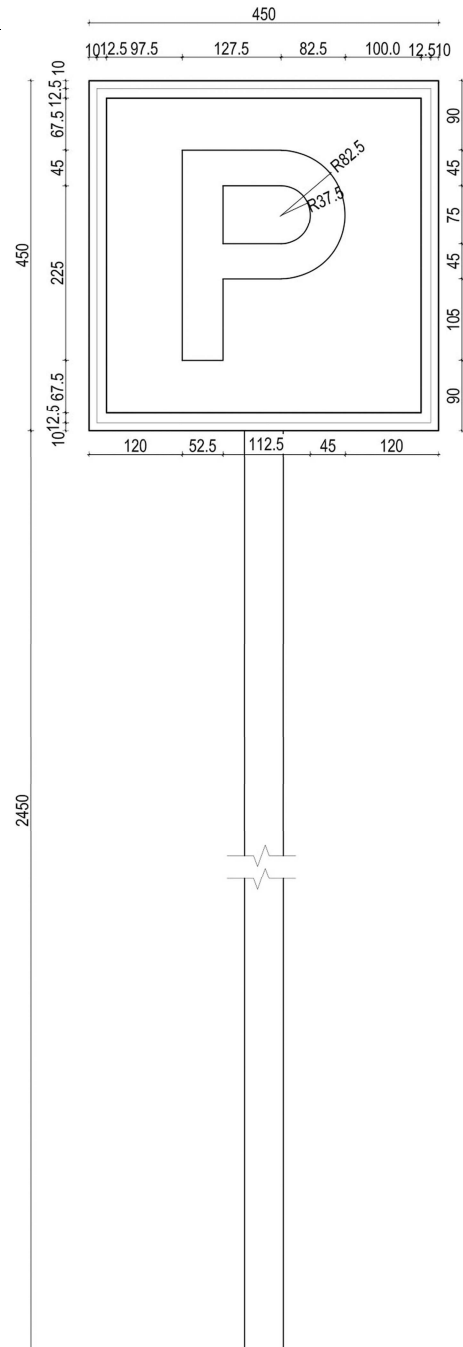
Artwork Dimensions:
450mm (w) x 450mm (h)

Placement:
Top of Signage placed at 2450mm from
GL.

Font Style:

General Notes:

This signage is used at parking area.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E14

Street Signage

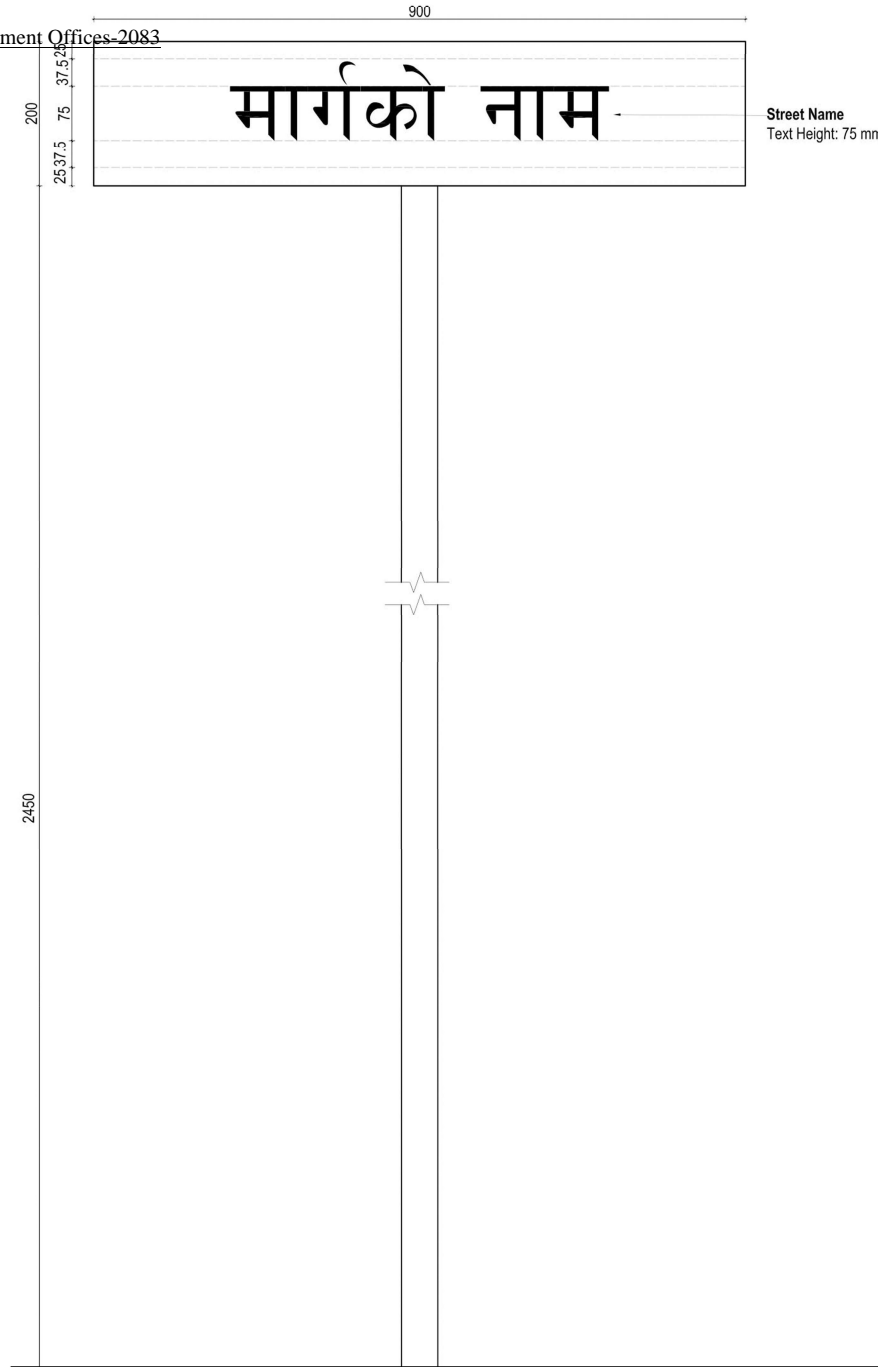
Artwork Dimensions:
900mm (w) x 200mm (h)

Placement:
Top of Signage placed at 2450mm from
GL.

Font Style:
Preeti

General Notes:

This signage gives information of the
street.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E15

Building I.D.

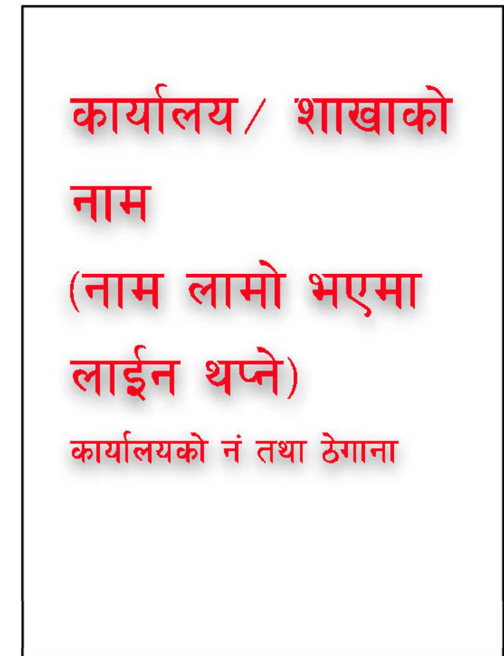
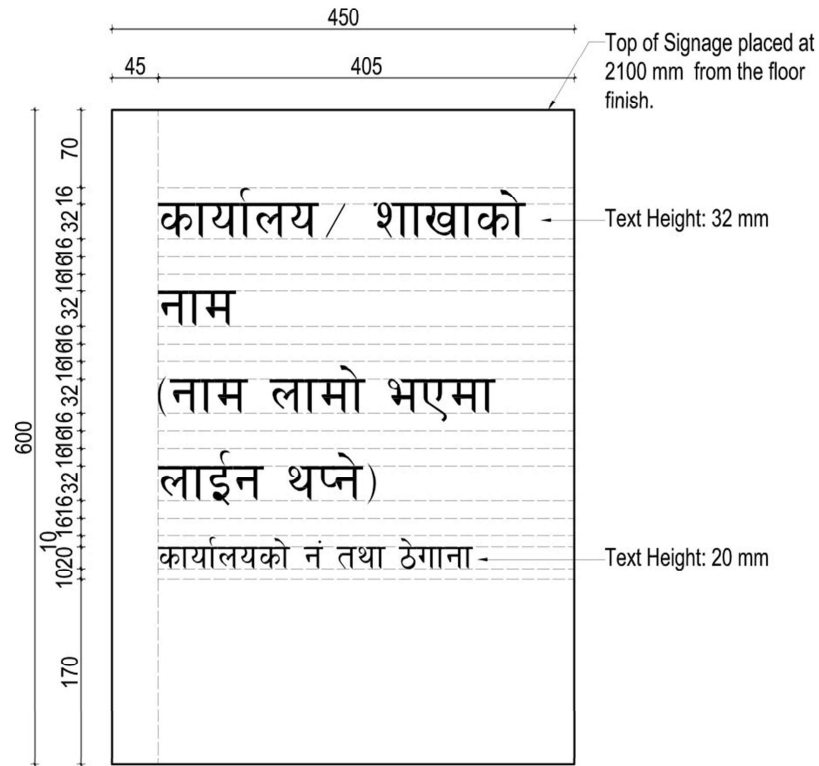
Artwork Dimensions:
450mm (w) x 600mm (h)

Placement:
Top of Signage placed at 2100mm from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be located at the main entrance to a building. This sign includes the address and either a building name or department. This sign is wall mounted.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E16

Building I.D.

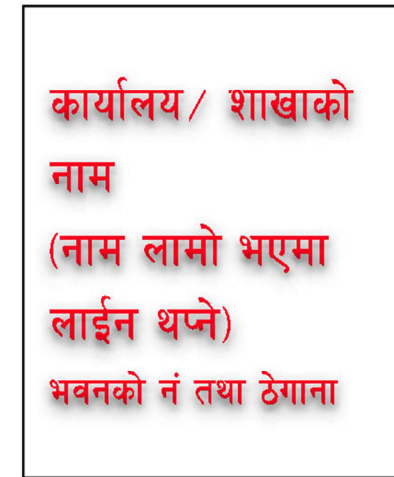
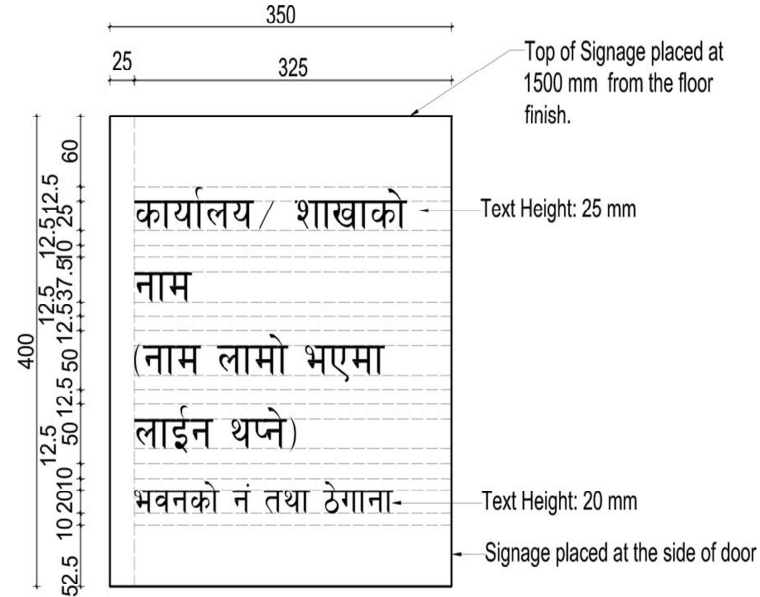
Artwork Dimensions:
350mm (w) x 400mm (h)

Placement:
Top of Signage placed at 1525 from floor finish at the side of the door.

Font Style:
Preeti

General Notes:

This signage is to be located at the main entrance to a building and at the side of the door. This sign includes the address and either a building name or department. This sign is wall mounted.



External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

315

Signage Type E17

Building I.D.

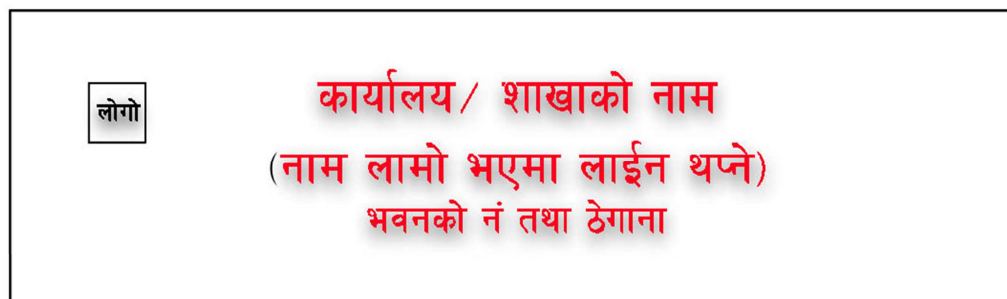
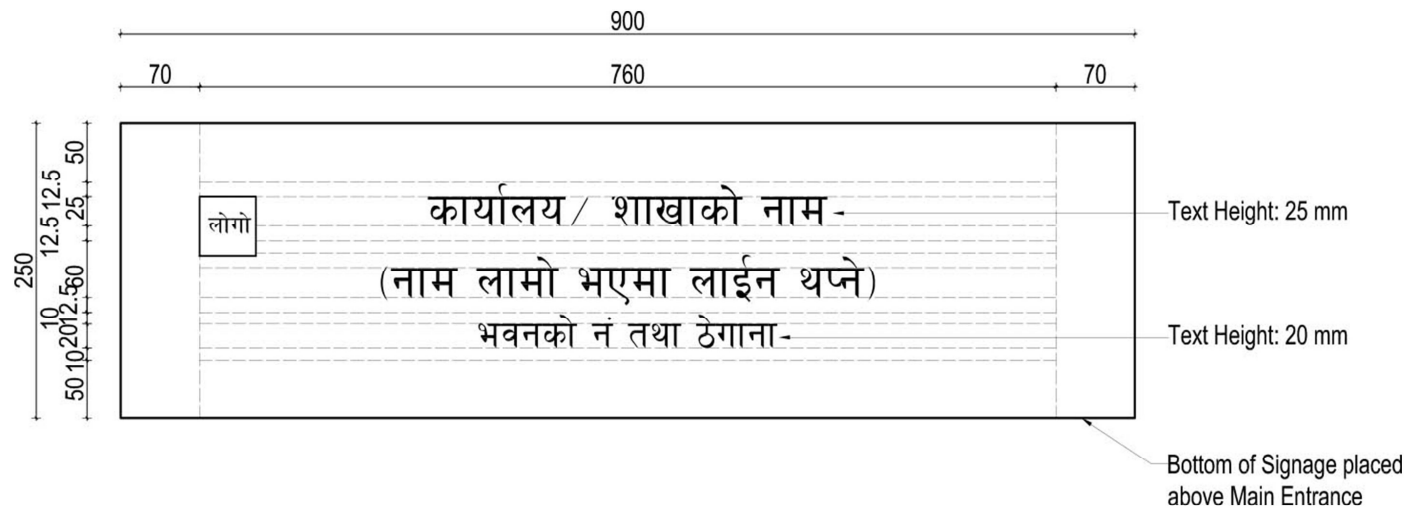
Artwork Dimensions:
900mm (w) x 250mm (h)

Placement:
Signage placed above the main door.

Font Style:
Preeti

General Notes:

This signage is to be located above main entrance to a building. This sign includes the address and either a building name or department. This sign is wall mounted.



Signage Type E18

Building I.D.

Artwork Dimensions:
2200mm (w) x 700mm (h)

Placement:
Signage attached to a canopy or placed
on top of the building.

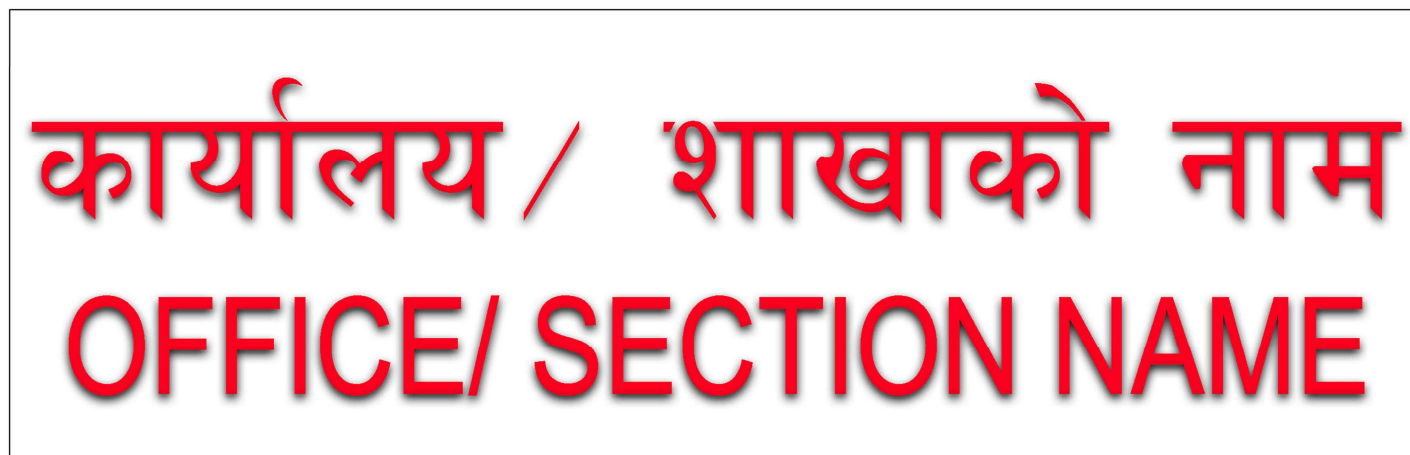
Font Style:
Preeti
Arial



General Notes:

For locations where a building sign can't be located on a flat surface. A sign placed on the door canopy face, may suit the location better.

This sign is generally read at longer distance so the type size of office name needs to be a minimum of 150mm.



Please note: signage dimensions can be adjusted to suit location

Signage Type E19

Building I.D.

Artwork Dimensions:
2500mm (w) x 700mm (h)

Placement:
Signage attached to a canopy or placed
on top of the building.

Font Style:
Preeti
Arial



Office/ Section Name
Text: Height 150 mm; centered
vertically and horizontally
Raised lettering

Office/ Section Name
Text: Height 150 mm; centered
vertically and horizontally
Raised lettering

General Notes:

For locations where a building sign can't be located on a flat surface. A sign placed on the door canopy face, may suit the location better.

This sign is generally read at longer distance so the type size of office name needs to be a minimum of 150mm.



Please note: signage dimensions can be adjusted to suit location

Signage Type E20

Building I.D.

Artwork Dimensions:
2500mm (w) x 1100mm (h)

Placement:
Signage attached to a canopy or placed
on top of the building.

Font Style:
Preeti
Arial

General Notes:

For locations where a building sign can't be located on a flat surface. A sign placed on the door canopy face, may suit the location better.

This sign is generally read at longer distance so the type size of office name needs to be a minimum of 150mm.

Please note: signage dimensions can be adjusted to suit location

External Signage Templates

Physical Infrastructure and Standardized Layout of Government Offices-2083

Signage Type E21

Building Information

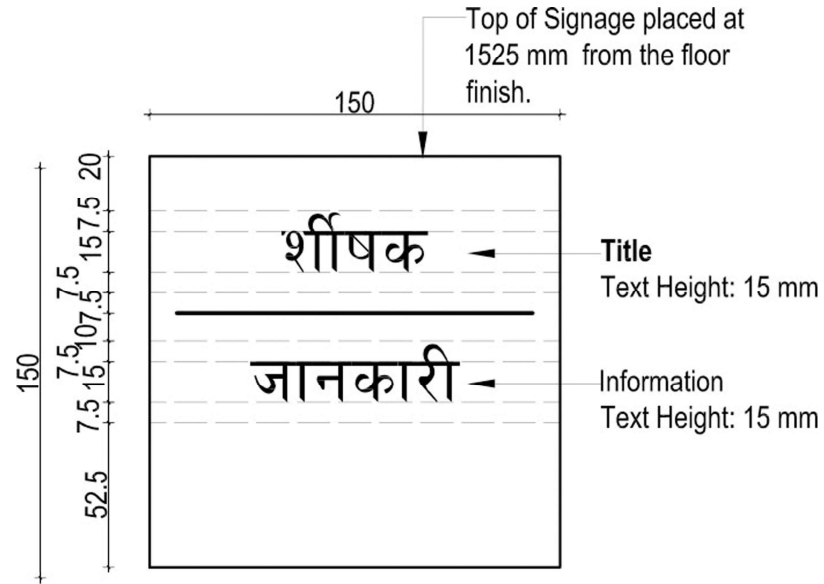
Artwork Dimensions:
150mm (w) x 150mm (h)

Placement:
Top of Signage placed at 1525 mm from floor finish.

Font Style:
Preeti

General Notes:

This signage is to be used at locations where an external notice needs to be displayed.

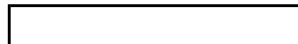


Recommended List for External Signage

S.N.	DESCRIPTION	Signage Type	MATERIAL	COLOR	
				FOREGROUND (Text, Pictures)	BACKGROUND
1	Free Standing Monolith	E1	Concrete, Brick and Plaster Finish	White	Blue
2	Wall Mounted Signage	E2	Acrylic, Metal	White	Blue
3	Vehicular Directional	E3, E4	Acrylic, Metal	White	Blue
4	Pedestrian Directional	E3, E5	Acrylic, Metal	White	Blue
5	Parking Area ID	P	Acrylic, Metal	White	Blue
6	Site Information	E7	Acrylic, Metal	White	Blue
7	Reserved Parking ID	E8	Acrylic, Metal	White	Blue
8	Parking Area ID	E9	Acrylic, Metal	White	Blue
9	Area ID	E10	Acrylic, Metal	White	Blue
10	Accessibility Signage	E11	Acrylic, Metal	White	Blue
11	Street Signage	E12	Acrylic, Metal	Black/ Red	White
12	Street Signage	E13, E14	Acrylic, Metal	White	Blue
13	Building ID	E15, E16, E17, E18, E19, E20	Acrylic, Metal	Red	White
14	Building Information	E21	Acrylic, Metal	White	Blue

Legends

White



Blue



Red

