UNIT 1 FOUNDATIONS

Structure

1.1 INTRODUCTION

Foundations form an important part of building construction. The forces and moments acting on a structure have to be ultimately transmitted to the ground and this is achieved by means of foundations. The loads on a building are transmitted downwards, floor by floor by means of columns and/or walls. If these are directly set on the ground, the pressures under them would be so much that either the soil will give way or large and uneven settlements would take place. In order to prevent this, the load is spread over a wider area by means of foundations such as footings, strips, rafts etc. At the same time, we have to ensure that the stresses in the elements of foundation like concrete, steel masonry etc. are within the specified limits.

The crust of the earth, over which the foundation rests, consists of various types of soils and rocks having widely different characteristics and properties. Further, the presence of subsoil water affects some of these properties. Before foundations are designed, we should know the details of the soil characteristics.

Generally, one is confronted with a situation where the desired land has been acquired and the foundation for the proposed building has to be designed taking into consideration the soil characteristics at the site. For important and heavily loaded structures, it may be worthwhile to take into consideration the necessary soil properties and other features at the site, before acquiring the land.

In earlier days, the design of foundations was based more on experience and intuition, but modern developments in Soil Mechanics have enabled us to understand, in greater detail, the properties of soil and the mechanism of load transfer from the building to the ground.

In this unit, you will learn about the various types of building foundations, where they are used and their constructional details.

Objectives

After studying this unit, you should be able to

- classify the various types of building foundations,
- describe the tests used for site investigation,
- establish the criteria for selecting the type of foundations,
- describe the constructional details of the commonly used foundations, and
- explain the design steps of wall footing.

1.2 SITE INVESTIGATIONS

The surface crust of the earth consists broadly of rocks and soils. Their engineering properties are largely dependent on the particle size, shape, texture, the bedding, chemical composition etc.

Rocks are classified as follows :

(a) igneous (such as granite) formed by cooling and solidification of molten lava material,

(b) sedimentary (like sand stone) formed by deposition of particles in layers, and

(c) metamorphic (like slates) formed by recrystallisation of existing igneous or sedimentary rocks under the action of great pressure and/or high temperature.

Generally, a rocky strata is a good base for foundation unless it is disintegrated or has faults, fissures etc.

Soil can be classified into the following categories :

Sands and Gravels

These are non-cohesive materials with good shear strength. The structural properties depend on density and particle size distribution. Size of particles of gravels ranges from 75 mm to 4.75 mm while that of sand from 4.75 mm to 75 microns.

Clays

These are cohesive with low shear strength and plastic in nature, prone to shrinkage and swelling depending on water content. Particle size is below 2 microns.

Silt

These are fine grained soil of particle size between 75 microns to 2 microns with little or no plasticity, and are compressible. In the presence of clay, it exhibits plasticity.

Sandy and gravely strata do not normally pose foundation problems while much more care is required in the case of clays and silts.

The first step in deciding about the foundation of a building is to have a site investigation carried out. Site investigation would cover all the techniques and enquiries to gather detailed information regarding the site, including study of maps, topographic surveys, reconnaissance surveys, soil investigations, climatic data etc. As a result of such investigations, following information should be available :

(a) topography of site, contour maps, with details of streams, ditches, ponds, wells, trees, rock outcrops, high transmission electric lines etc.,

(b) locations of underground sewers, waterlines and cables,

(c) liability to flooding,

(d) ground water details,

(e) details of any structures existing at the site or nearby with details of their foundations, including information regarding failures, cracks etc.,

(f) a detailed soil investigation report including bore charts, results of laboratory tests on soil samples and recommendations regarding depth and bearing capacity for foundation design, and

(g) meteorological data.

The detailed soil report would form the basis for the choice and design of foundation. While for small single storied buildings, it may be sufficient to have a few trials pits, for larger structures or where there are doubts regarding the substrata, borings at site taken to sufficient depth would be required to collect and analyse the soil samples. The depth and the number of borings would depend on the type of structure and the soil conditions.

1.2.1 Trial Pits and Borings

Trial pits consist of making excavation at site enabling examination of the subsoil and collection of samples. This method can be adopted for small depths of about 3 m. The depth of exploration required to be carried out is normally, one and a half times to twice the width of the foundation.

For deeper exploration, borings have to be carried out. These can be *auger boring, percussion boring, rotary boring* etc. From these borings, undisturbed/disturbed soil samples can be collected.

The samples collected from the pits/borings are listed in the laboratory to assess the various properties like grain size distribution, liquid and plastic limit, unit weight of soil, specific gravity, natural moisture content, compressive strength etc. From these investigations, a chart indicating the depths of various strata can also be prepared.

1.2.2 Field Tests

Plate load test and penetration tests are very useful field tests for site investigation. The set-up and other details of these tests are given in the following paragraphs.

Plate Load Tests

It is one of the earliest tests to be performed to determine the bearing capacity of soil. The test consists of making a pit, usually at foundation level and measuring the settlements of a circular or square mild steel plate not less than 25 mm in thickness and 300 to 750 mm in size subject to gradual load increments. From the test results, load vs settlement curve is plotted and the ultimate bearing capacity of the soil is arrived at. This test has the following limitations :

(a) The results are indicative of the character of soil within a depth of less than twice the width of the bearing plate which is usually 300 to 750 mm. Since the actual dimensions of foundations are larger, the settlements and shear resistance will depend on a much thicker stratum of the sub-soil.

(b) It is a short duration test and does not give an idea about consolidation settlement particularly in cohesive soils. Thus, the results of the test could be misleading if the character of soil changes at shallow depths, which is not uncommon.

(c) While for clayey soils, the bearing capacity (from shear consideration) for a larger foundation is almost the same as for the smaller test plate; while in the case of dense sandy soils, the bearing capacity increases with the size of foundation and hence, in such cases; the plate load test gives a conservative value.

Penetration Tests

These tests involve the measurement of the resistance to penetration of a sampling spoon, a cone or other shaped tools under dynamic or static loading. The commonly used tests are the standard penetration test and the static and dynamic cone penetration tests. From these tests, the soil strata at various depths alongwith their properties can be obtained. From these penetration values, bearing capacity can be assessed.

Soil exploration should be able to provide necessary data to evaluate the following parameters :

(a) safe bearing capacity of the soil,

(b) subsoil water level, and

(c) probable settlement of the structure under the design load.

The test report generally gives recommendations regarding the depth of foundation and safe bearing capacity.

1.3 BEARING CAPACITY OF SOIL

The purpose of the foundation being to transmit the load of the structure to the ground, it is necessary to know the capacity of the soil (bearing capacity) to withstand this pressure. The definitions of various terms used in connection with bearing capacity are given below :

Ultimate Bearing Capacity

If the load at the base of footing is gradually increased, a stage will reached when the load will cause a shear failure in supporting soil. The maximum gross intensity of loading that the soil can support before it fails in shear is called the ultimate bearing capacity.

Safe Bearing Capacity

It is the maximum intensity of loading the foundation will safely carry without the risk of shear failure.

Allowable Bearing Capacity

It is the maximum net intensity of loading that can be imposed on the soil with no possibility of excessive settlement.

The ultimate bearing capacity can be determined

(a) by plate load test,

(b) theoretically, based on the characteristics of various types of soils, and

(c) by making use of penetration and other test results.

The bearing capacity that can be adopted for the design of a foundation depends on the characteristics of the soil, the depth and dimensions of the foundation and the degree of settlement that can be allowed for the structure. There are two approaches to the determination of the bearing capacity.

Based on the shear strength characteristics of the soil, the ultimate bearing capacity of the soil at a given depth for specific dimensions of the foundation can be calculated. A factor of safety can be applied to the ultimate bearing capacity to arrive at the safe bearing capacity. If calculation of settlements indicates that it is within the permissible limit then the safe bearing capacity would be the allowable bearing capacity. However, if the calculation of the settlements shows that it is beyond acceptable limit then a lower value has to be adopted for the allowable bearing capacity based on the permissible settlement. The second approach is to determine the bearing capacity on the basis of in-situ tests.

In the case of cohesionless soils, the main problem is to obtain satisfactory undisturbed soil samples for determination of shear strength. However, generally in such soils the allowable bearing pressures are governed by settlement consideration rather than ultimate bearing capacity due to shear failure. In cohesionless soils, therefore, the bearing capacity can be calculated on the basis of penetration tests and empirical methods relating allowable bearing pressure to permissible settlements for foundations of given dimensions.

The procedure of calculation of ultimate bearing capacity on the basis of shear strength characteristics is widely used in the case of silts and clays.

For a foundation on rock, allowable bearing pressures are governed more by the stresses on the foundation elements.

1.4 SETTLEMENT OF FOUNDATIONS

By settlement we mean the vertical downward movements of the foundation. The effect of settlement on the structure depends on its magnitude, both absolute as well as relative with respect to the different parts of the foundation. Settlement may be caused by :

(a) the weight of the structure and the superimposed loads,

(b) subsidence due to mining,

(c) shrinkage due to change in moisture content, and

(d) general earth movement.

Settlements, that take place when the static load is within the range of the safe bearing capacity of the soil, consists of the following elements :

(a) Elastic deformation which takes place immediately on application of load,

(b) Primary consolidation of foundation soil resulting from expulsion of pore water,

(c) Secondary compression of foundation soil, and

(d) Creep of the foundation soil.

It the structure settles uniformly, there will be no damage but if the settlement is excessive the underground service lines may be affected. In actual practice, as the soil is not a purely homogeneous material and superimposed loadings are not equal, settlements are non-uniform, inducing corresponding stress in the structure. Depending upon the extent of these stresses, the settlements have to be limited by appropriate designs.

Based on the loading pattern and the soil characteristics the settlements can be calculated and if it exceeds the desirable limits, the foundation has to be redesigned.

The permissible values of settlement for different types of structure are given in IS : 1904-1986. The same can be referred for further details.

1.5 DEPTH OF FOUNDATION

The depth to which foundation should be taken depends on the following principal factors :

(a) Securing of adequate allowable bearing capacity,

(b) In the case of clayey soils, penetration into the soil has to be below the zone where shrinkage and swelling due to seasonal weather changes and due to trees and shrubs are likely to cause appreciable movements,

(c) In fine sands and silts penetration has to be below the zone in which trouble may be expected from frost,

(d) The maximum depth of scour whenever relevant (say, in bridge piers) should also be considered and the foundation should be located sufficiently below this depth, and

(e) It should be below the top soil, miscellaneous fill, tree roots etc.

All foundations should be taken down to a minimum depth of 0.5 m below natural ground level. In filled-up ground it may be necessary to go beyond the depth of fill or take special precautions. In such cases, it may be necessary for economic considerations to have the foundation at a higher level, and get the difference in level between the base of foundation and the level of excavation filled up with either :

(a) concrete of allowable compressive strength not less than the allowable bearing pressure on the soil, or

(b) incompressible fill material, for example sand, gravel etc. in which case the width of fill should be more than the width of foundation for dispersion of load on either side of the base of foundation.

In sloping grounds, the horizontal distance from the bottom edge of the footing to the ground surface shall be at least 60 cm for rock, and 90 cm for soil. A line drawn at an angle of 30^o to the base from the outer edge should not intersect the sloping surface (Figure 1.1).

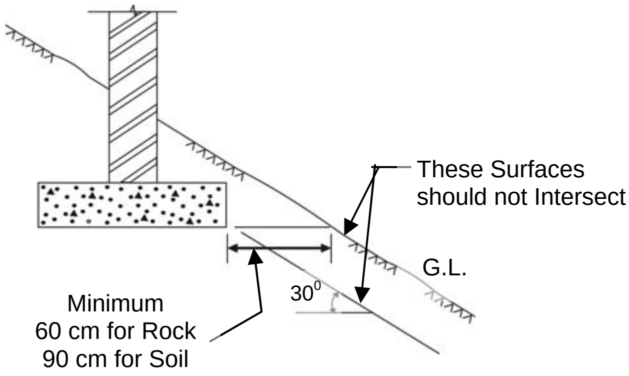


Figure 1.1 : Footings on Sloping Ground

Foundation near Existing Buildings

The minimum horizontal distance between existing and new footings shall be at least equal to the width of the wider footing. In important cases, analysis of bearing capacity and settlement shall be carried out.

Foundation at Different Levels

In the case of footings on granular soil, the distance between the footings should be such that a line drawn between the lower adjacent edges of the footings shall not have a slope steeper than one vertical to two horizontal as shown in Figure 1.2.

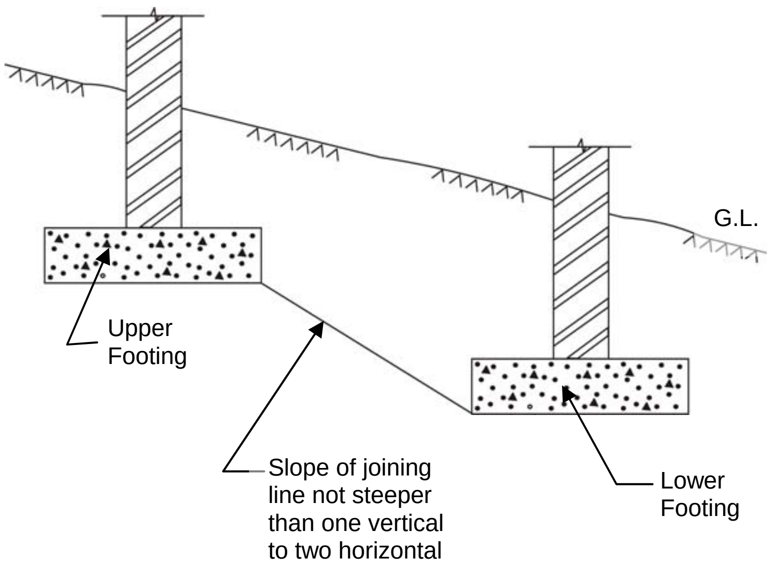


Figure 1.2 : Footings on Granular Soil

In clayey soils, a line drawn between the lower adjacent edge of the upper footing and the upper adjacent edge of the lower footing shall not have a slope steeper than one vertical to two horizontal as shown in Figure 1.3.

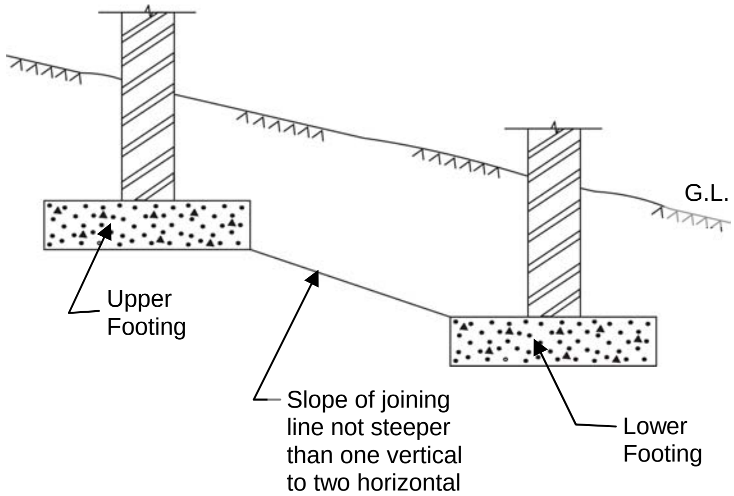


Figure 1.3 : Footings on Clayey Soil

SAQ 1

(a) What is the information regarding the properties of soil to be obtained from site investigations?

(b) Distinguish between ultimate, safe and allowable bearing capacities.

SAQ 2

(a) What are the causes for settlement of foundations?

(b) What are the factors to be considered while deciding the depth of a foundation?

1.6 EXCAVATION FOR FOUNDATION

Site Clearance

Before the excavation for the proposed foundation is commenced, the site shall be cleared of vegetation, brushwood, stumps of trees etc. Roots of the trees shall be removed to at least 30 cm below the foundation level. The pits formed due to roots of trees, old foundations etc. shall be filled up with soil and compacted.

Setting Out

A bench mark shall be established at the site by a masonry pillar and connected to the nearest standard benchmark. Levels of the site should be taken at 5 to 10 m intervals depending on the terrain and the importance of the building. The centre lines of the walls are marked by stretching strings across wooden pegs driven at the ends. The centre lines of the perpendicular walls are marked by setting out the right angle with steel tapes or preferable with a theodolite. The setting out of walls shall be facilitated by having a permanent row of pillars (not less than 25 cm wide) parallel to and at a suitable distance beyond the periphery of the building so that they do not foul with the excavation. The pillars shall be located at the junctions of the cross walls and external wall and shall be bedded sufficiently deep so that they are not disturbed during excavation for foundation. The centre lines of the walls shall be extended and marked on the plastered tops of the pillars. The tops of the pillars may be kept at the same level, preferably the plinth level. In rectangular or square settings, the diagonals shall be checked to ensure accuracy of setting out.

Excavation

For small buildings, excavation is carried out manually by means of pick axes, crowbars, spades etc. In case of large buildings and deep excavation, mechanical earth cutting equipment can be used.

For hard soils when the depth of excavation is less than 1.5 m, the sides of the trench do not need any external support. If the soil is loose or the excavation is deeper, some sort of shoring is required to support the sides from falling. Planking and strutting can be intermittent or continuous depending on the nature of soil and the depth of excavation. In the case of intermittent or "open" planking and strutting the entire sides of trenches are not covered. Vertical boards (known as poling boards) of size 250 × 40 mm of the required length can be placed with gaps of about 50 cm (Figure 1.4). These shall be kept apart by horizontal waling of strong timber of section 100 × 100 mm at a minimum spacing of 1.2 m and strutted by a cross piece of 100 × 100 square or 100 mm diameter. In case of soft soils continuous or "close" planking is adopted and the vertical boards are kept touching each other without any gap as shown in Figure 1.5(a).

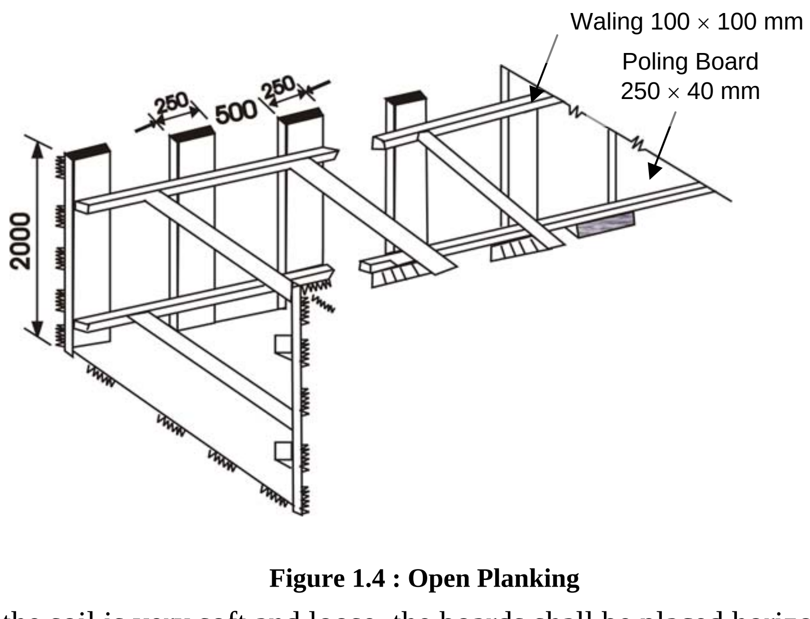
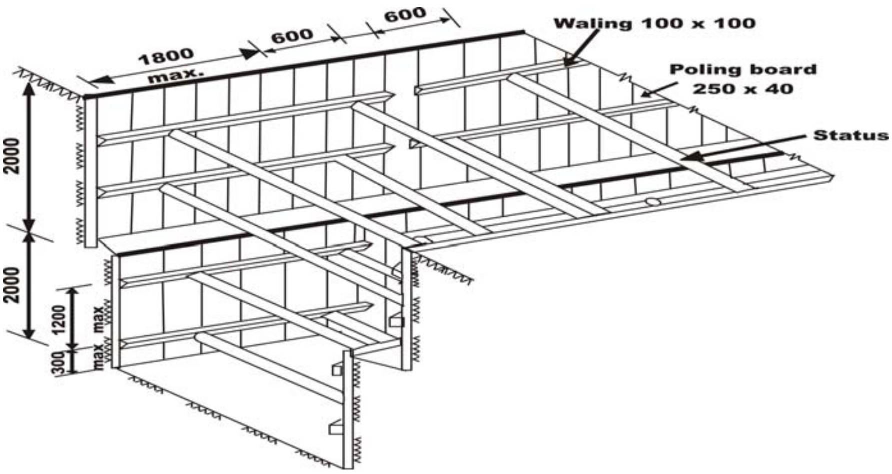


Figure 1.4 : Open Planking

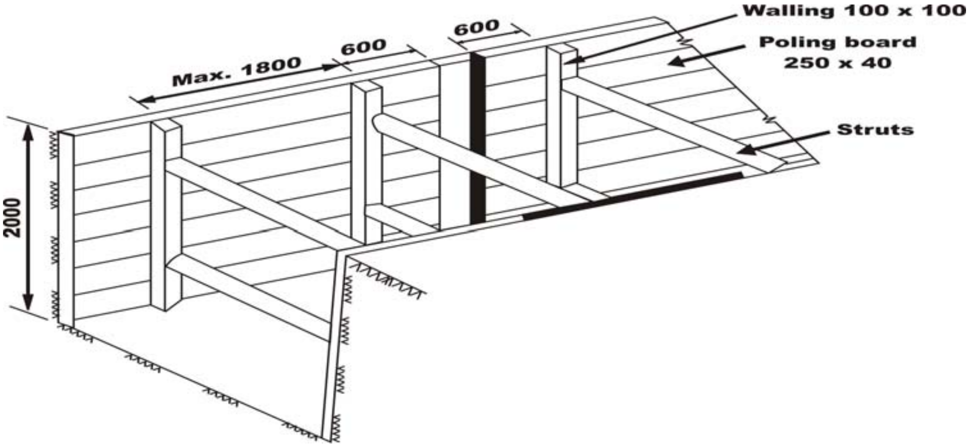
If the soil is very soft and loose, the boards shall be placed horizontally against the sides of the excavation and supported by vertical waling boards, which shall be strutted to similar timber pieces on the opposite side of the trench as shown in Figure 1.5(b).

Care has to be taken while withdrawing the timber members after completion of the foundation work, so that there is no collapse of the trench.

Construction of foundation below the subsoil water level poses problems of water logging. It is, therefore, very often necessary to dewater the area of excavation. Several operations have to be carried out within the excavation, like laying bed concrete, laying of RCC raft slab and construction of masonry etc. Therefore, work can be carried out more efficiently if the excavation area is kept dry. To keep the area of excavation dry, water table should be maintained at least 0.5 m below the bottom of the excavation. There are several methods available for lowering the water table. Information obtained from site and soil investigation would be useful in deciding the most suitable and economical method of dewatering. For fairly dense soil and shallow excavations, the simplest method is to have drains along the edges of the excavation and collect water in sumps and remove it by bailing or pumping. This is the most economical method and is feasible of being executed with unskilled labour and very simple equipment.



(a) Close Planking



(b) Planking in Very Soft and Loose Soil

Figure 1.5

Where large excavations such as for rafts are to be dewatered, well point system can be employed. Well point consists of a perforated pipe, 120 cm long and 4 cm in diameter with a valve to regulate flow and a screen to prevent entry of mud etc. These well points are installed along the periphery of the excavation at the required depth and spaced at about 1m. The exact spacing can be decided on the basis of the type of soil. Well points are surrounded by sand gravel filter and have riser pipes of 5 to 7.5 cm diameter. These pipes are connected to a header pipe, which is attached to a high capacity suction pump. The ground water is drawn out by the pumping action and is discharged away from the site of excavation as shown in Figure 1.6.

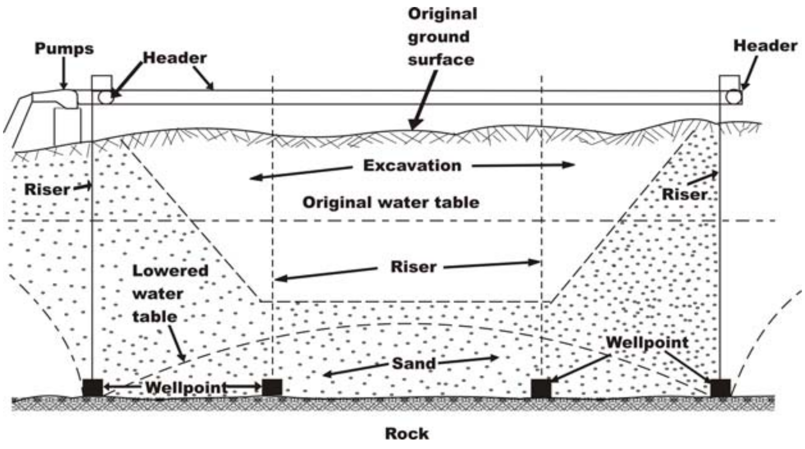


Figure 1.6 : Lowering Water Table by Well Point

Foundation Concrete

In the case of a masonry wall, the footing is generally of cement concrete mix of ration 1 : 4 : 8 : or 1 : 5 : 10 (cement : sand : coarse aggregate). The size of coarse aggregate is limited to 40 mm. Lime concrete can also be used for this purpose.

For important works, mixing of concrete should be done in a mechanical mixer. Concrete should be laid (not thrown) in layers not exceeding 15 cm and well compacted. The concrete should be protected by moist gunny bags after about 1 or 2 hours of laying. Regular curing should be started after 24 hours and be continued for 10 days. The masonry work over the bed concrete can be started after 3 days of laying the concrete but curing along with that of masonry shall be continued.

For RCC column footings and raft foundations, a leveling course of lean concrete of 75 mm is laid in order to have an even and soil free surface for placing the reinforcement.

SAQ 2

What are the methods to lower sub-soil water level for the purpose of excavation of foundations?

1.7 SELECTION OF FOUNDATION

The factors to be considered for the selection of the type of foundation for a given situation are as follows :

(a) The characteristics of the superstructure and the superimposed loads,

(b) Site conditions, type of soil and its allowable bearing capacity,

(c) Materials and machinery/equipment available for construction, and

(d) Relative costs.

1.8 TYPES OF FOUNDATION

Foundations can broadly be classified as depicted in flow diagram on next page. These are subsequently described in detail in following sections.

1.9 SHALLOW FOUNDATIONS

Generally, shallow foundations are those where the depth *D* is less than the width (*B*) of the foundation.

These cover such types of foundation in which load transfer takes place primarily through shear resistance of the bearing strata; and, such foundations are normally up to a depth of 3 m. The various types of shallow foundations used in building construction are described below.

1.9.1 Spread and Strip Footings

The basic purpose of this foundation is to spread the load over a larger area so that the soil is able to withstand the stress, and the safe bearing pressure is not exceeded. In such types of foundations, if the resultant of the load deviates from the centre line by more than 1/6 of its least dimension at the base of the footing, it should be suitably reinforced.

Wall Footings

In the case of brick walls, the width of section is increased by 1/4 brick (5 cm) offset on either side. The base rests on a plain concrete footing which projects 10 to 15 cm beyond the last brick offset as shown in Figure 1.7. The width at the base shall not be less than the width of the supported wall plus 30 cm.

The depth of each course can be one brick or multiples of brick thicknesses. In the case of stone masonry walls, the offsets could be 15 cm with the heights of the course as 30 cm. The depth of the concrete which is generally of 1 : 4 : 8 (1 Cement : 4 Fine aggregate : 8 Coarse aggregate) or 1 : 5 : 10 : (1 Cement : 5 Fine aggregate : 10 Coarse aggregate) mix should not be less than 15 cm. The angular spread of load from the wall should not be more than 1 vertical to 1/2 horizontal in masonry and 1 vertical to 1 horizontal for cement concrete.

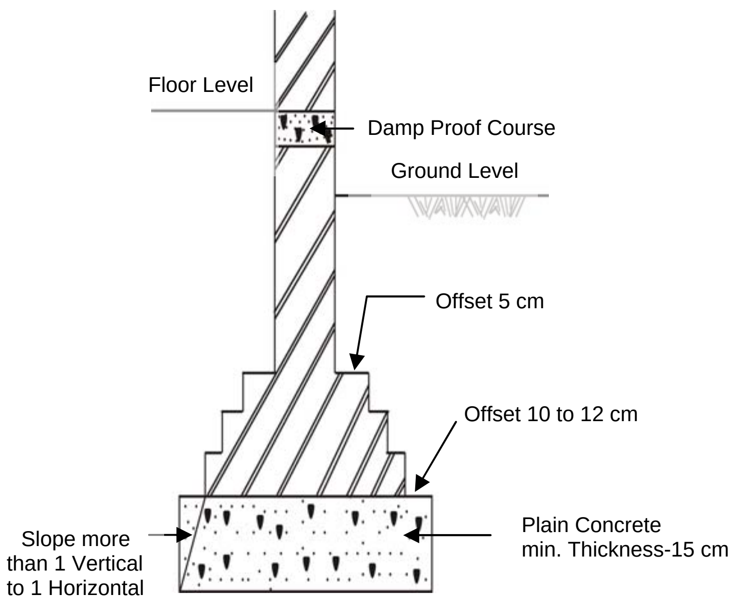


Figure 1.7 : Wall Footing

If the load on the wall is heavy or the soil is of low bearing capacity, reinforced concrete strip footing can be provided (Figure 1.8). The thickness of the strip can be reduced towards the edge to effect economy.

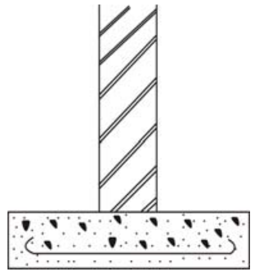


Figure 1.8 : Strip Footing

RCC Column Footings

These are generally square or rectangular. They are reinforced in both directions and are designed to withstand the upwards soil pressure as shown in Figure 1.9. The reinforcement of the column is taken right up to the bottom of the footing. The RCC footings are laid over a bed of lean concrete of about 75 mm thickness.

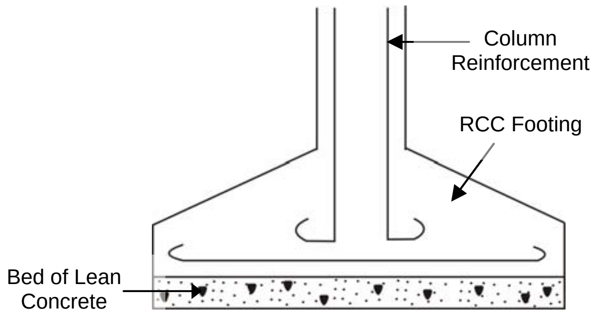


Figure 1.9 : RCC Column Footing

As the bending moment decreases towards the edge, the thickness can also be reduced accordingly. The minimum thickness at the edge shall, however, be not less than 15 cm. Stepped footings should be avoided as sudden changes in stress conditions are likely to be produced. The top of the footings can be sloped towards the edge in the shape of a pyramid. Steep slopes exceeding 1 in 2 would require formwork and hence, normally the slope is of the order of 1 in 4. In a foundation, it is important to ensure that a minimum cover of 40 to 50 mm is provided to prevent corrosion of reinforcement.

Combined Footings

When two column footings are near to each other or the foundations overlap, a combined footing can be provided. Such footings can be rectangular or trapezoidal in plan and its position is so adjusted that its centre of gravity coincides with that of the loads from the columns.

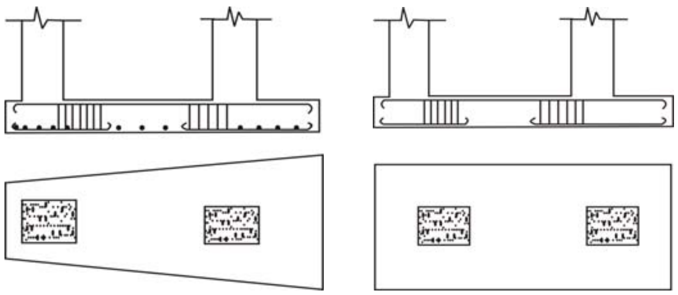


Figure 1.10 : Combined Footing

Cantilever or Strap Footings

At times, there are restrictions in space for the external columns due to adjacent buildings etc., and it would not be possible to place the footings centrally with respect to the columns. In such cases, the column is connected with the interior column by a beam so that the loads are shared as shown in Figure 1.11.

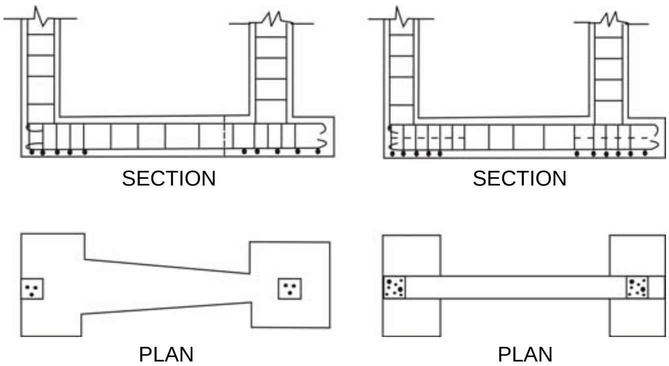


Figure 1.11 : Strap Footing

1.9.2 Grillage Foundation

When there is heavy load on steel columns and the soil is of low bearing capacity, grillage foundations can be provided. These consist of rolled steel joists in one or two layers that are encased in concrete with the overall dimensions being such that the soil pressure is within the allowable bearing capacity. Adequate gap must be provided between the flanges of the girders to enable the concrete to flow and fill the gaps. However, it should not be more than 1.5 to 2 times the flange width in order that the concrete and steel should act together. Concrete is not intended as a structural element but is used to keep the beams in position and prevent its corrosion. To prevent movement during concreting, the joists are connected through the webs by bolts with spacers. This type of foundation is expensive on account of the large amount of steel and is now rarely used.

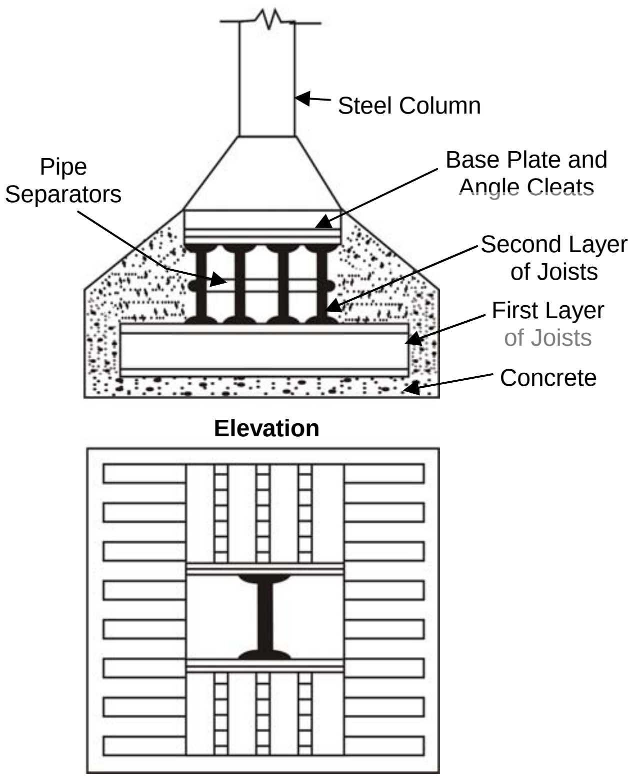
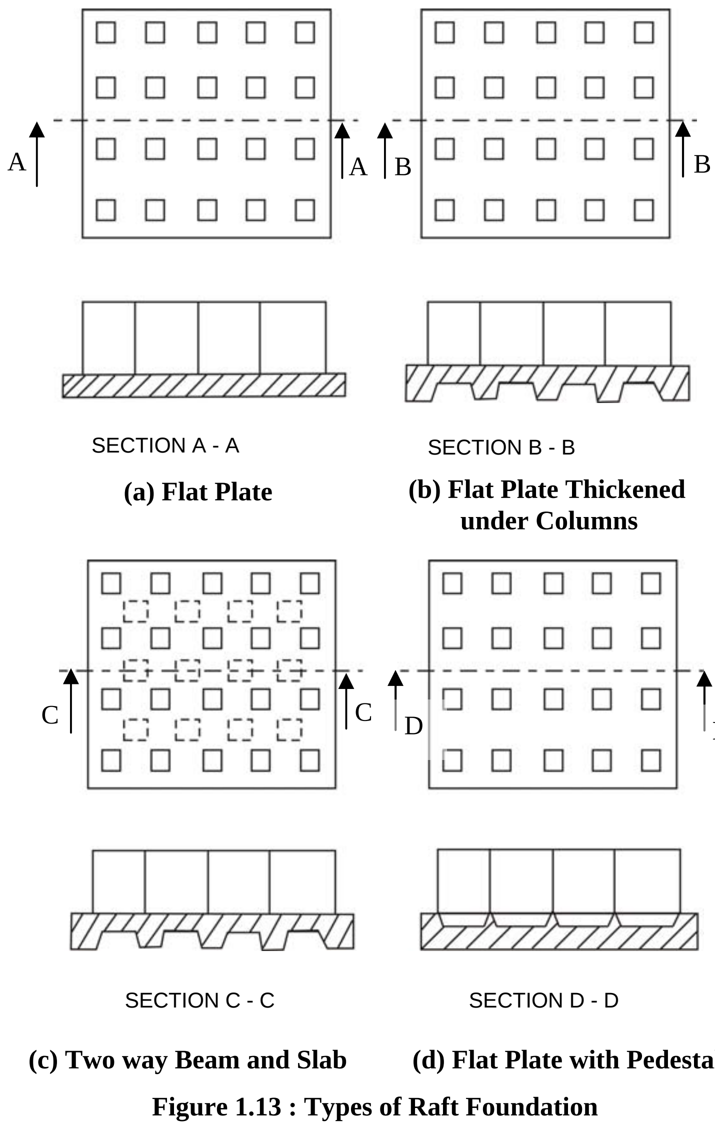


Figure 1.12 : Grillage Foundation

1.9.3 Raft Foundation

Where there are heavy loads on the columns and/or the soil has low bearing capacity, the individual footing or strips overlap or are too close to each other. In such cases raft foundations are adopted. If the footings cover more than half the area of the building, a raft foundation is likely to be economical. For buildings having basements particularly where subsoil water levels are high, it is advantageous to provide rafts. These can be designed to resist the water pressure and suitable water proofing treatment can be provided.

Basically a raft foundation consists of a thick reinforced cement concrete slab with reinforcement provided at the top and bottom in both directions. For fairly small and uniform column spacing and when the supporting soil is not very compressible, a slab of uniform thickness can be provided as shown in Figure 1.13.



(a) Flat Plate

(b) Flat Plate Thickened under Columns

(c) Two way Beam and Slab

(d) Flat Plate with Pedestal

Figure 1.13 : Types of Raft Foundation

If the loads are heavy, the slab can be thickened to take care of the shear and the negative moments. If the spacing between the columns is large, the loads are unequal and the soil is quite compressive, a beam and slab arrangement can be provided; raft slab in such a case acts as an inverted slab with T beams.

The depth of foundation for a raft shall generally be not less than 1 m. A bed of lean concrete of 75 to 100 cm thickness is provided to facilitate laying of reinforcement and concreting. It is economical to project the raft slab by about 30 to 45 cm beyond the face of the peripheral columns.

Where possible, the raft is so proportioned that its centre of gravity coincides with that of the column loads. If this is not possible, the eccentricity has to be taken into account in the structural design as well as in checking for the pressure on the soil.

SAQ 3

(a) Under what conditions will you adopt individual RCC footings, combined RCC footings and raft foundations?

(b) Under what circumstances would you adopt a steel grillage foundation? Explain the features of such a foundation.

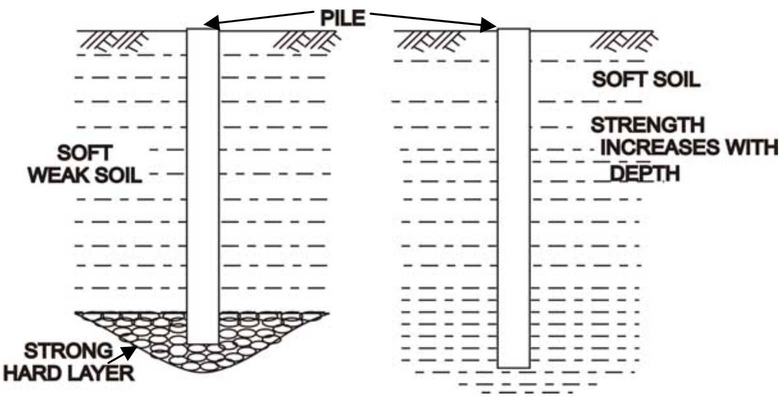
1.10 DEEP FOUNDATIONS

Foundations with D/B ratio greater than 15 is called deep foundations. In deep foundation, the load is supported partially by frictional resistance around the foundations and the rest by bearing at the base of the foundation.

1.10.1 Pile Foundations

If the soil in the top layers near the ground does not have adequate bearing capacity it would be necessary to transfer the load to the lower strata. For buildings, this is achieved by means of piles.

Piles are long column-like members which transmit load of the structure through a weak material to an underlying hard strata. If the bearing stratum is hard and impenetrable like rock or hard dense gravel, a pile derives its strength mainly by bearing and is known as *end bearing pile as* shown in Figure 1.14(a).



(a) End Bearing Pile **(b) Friction Pile**

Figure 1.14 : Different Types of Piles (Based on Mode of Load Transfer)

Piles driven in soil which increasingly becomes stiff with depth derive their bearing capacity from the friction along the surface of the pile and are known as *friction piles* as shown in Figure 1.14(b). Normally, in a pile, part of the load is carried by friction and part by end bearing.

Sheet piles are used as retaining structures and bulk heads.

Tension or uplift piles are used to resist uplift forces due to hydrostatic pressure or overturning moment due to horizontal forces.

Compaction piles are used to compact granular soils to increase their bearing capacity. They are not normally required to carry any load.

Piles can also be used to resist uplift pressures on structures as also to withstand lateral forces. Such piles are called *anchor piles.*

Anchor piles are used to provide anchorage against horizontal pull in a sheet pile.

A pile which is installed at an angle to the vertical is known as a *batter or raker pile*.

Fender piles are used to protect water front structures against impact from ships.

Materials for Piles

Piles, particularly of timber have been in use from ancient times and can be considered as one of the earliest innovations in foundation engineering. However, it is only in the past few decades that appropriate methods have been evolved to analyse and design piles.

Construction of pile foundation requires a careful choice of the type of pile and methodology of execution taking into consideration the soil strata, the level of subsoil water, the load characteristics of the structure, limitation of settlements and any other special requirements. The availability of materials, equipment and economic factors should also to be considered.

Piles can be of timber, steel or concrete. The earliest types of piles used were of timber while presently concrete piles are used to the maximum extent. Steel piles are expensive and rarely used.

Timber Piles

These can be used for relatively lightly loaded structures located in compressive types of soils with high ground water level. Timber has a high weight to strength ratio and can be cut, shaped and handled easily. If timber piles are wholly in a submerged condition they have a long life. If the subsoil water level is high, the piles can be cut off, at the top, below this level and a concrete pile cap is as shown in Figure 1.15(a).

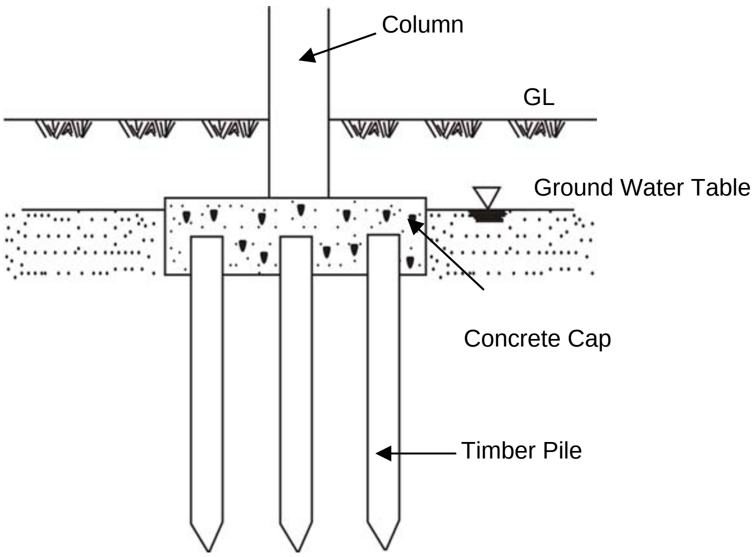


Figure 1.15(a) : Timber Pile with Concrete Cap

Timber used for the piles has to be of good quality like teak, sal, deodar etc. it should be straight grained and free from defects. The piles shall be treated with timber preservative. Timber piles can be of square or round section. *Round section is preferable as cutting to square shape removes part of the outer sapwood which is absorptive to preservatives*.

Piles are driven into the soil by the drop hammer of a pile driving machine. For facilitating driving, the lower end is provided with a cast iron conical shoe and the head is prevented from splitting by means of a mild steel hoop as shown in Figure 1.15(b).

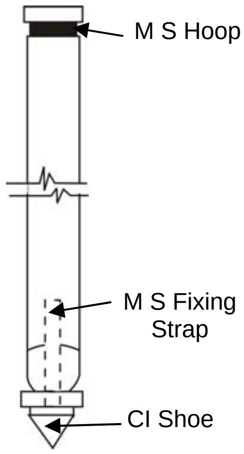


Figure 1.15(b) : Timber Pile with MS Hoop and CI Shoe

Timber piles are relatively cheaper and easy to drive but get deteriorated and decayed particularly when subjected to alternative drying and wetting. They cannot be used for heavily loaded structures.

Steel Piles

High strength of steel makes it a good material for piles. Steel piles can be in the form of rolled steel H-sections or seamless/welded steel pipes. They can be directly driven into the ground for use as piles. The tubes can be open ended or close ended. In the case of open ended pipes, after the piles are driven, the earth inside is cleared out by water jetting and filled with concrete. The closed ended pipes are provided with a shoe to facilitate driving and these are also normally filled with concrete.

Because of its inherent strength, a steel pile can withstand the large impact of the pile driving hammers and can penetrate through relatively hard strata and boulders. The total length of pile can easily be extended by welding additional piece(s) or shortened by cutting. Steel piles cause little ground displacement and hence, can be driven at close intervals, or near existing buildings. They require less storage space and can be handled easily as compared to precast RCC piles.

The disadvantages are the possibility of corrosion and lesser frictional resistance with reference to transfer of load. These piles are more expensive than other types of piles and hence, they are not used very widely. They can be used for very heavy loads and for foundations of bridges, trestles etc.

Concrete Piles

Concrete piles can be divided into following two categories :

(a) precast concrete piles, and

(b) cast in-situ concrete piles.

Precast Concrete Piles

These piles are usually cast near the site of work in specially prepared casting yard with adequate supervision and control to produce good quality concrete. The casting yard should be a levelled firm area with proper drainage and located as close to the site as possible so that expenses on transporting are limited. The formwork of steel or timber should be of the required specifications and should be properly cleaned and oiled before placing the reinforcement cage. As far as possible, longitudinal reinforcement shall be in one length. In case this is not possible, overlaps shall be staggered and preferably joints shall be butt welded. Necessary stirrup shall be provided and they shall be closely spaced near the top and bottom of the pile to avoid damage due to high impact stresses. The concreting of each pile has to be in one continuous operation and thoroughly compacted with vibrator. The exposed face must be trowel finished to provide a dense even surface. Side shuttering can be removed after a day and piles cured by wet gunny bags for a period of ten days. The piles should be carefully examined to see whether there are any defects, before they are taken to site for driving.

These piles are reinforced not only to carry the load on the foundation but also to withstand the stresses produced in lifting the piles and carrying them to the place of installation. In precast concrete piles, generally the reinforcement required to withstand the stresses during handling and driving are more than that required to take the load on the foundation. Piles can be lifted by hooks or clamps at a single point or at two points (Figure 1.16). Hooks can be embedded at the time of casting or proper markings made so that slinging is done correctly. The reinforcement has to be suitably designed according to the proposed mode of lifting. The high stresses produced while lifting and driving, necessitates proper structural design of the pile to take the bending and shear stresses. Once the pile is driven into the ground, much of the steel becomes redundant as the stresses are mainly compressive. Piles can also be manufactured in a factory but transportation of long piles to the site could pose problems.

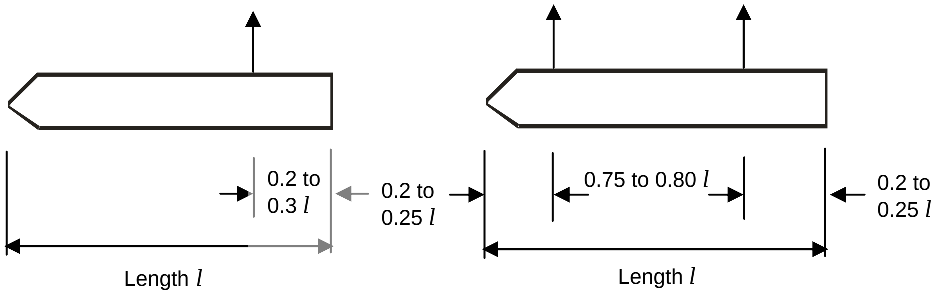


Figure 1.16 : Lifting of Precast Piles

If it has been decided to adopt precast piles for the foundation, the length of piles has to be assessed fairly correctly, as cutting the piles or extending them cannot be done easily. They also require large casting yards and heavy equipment for handling and driving.

However, in situations where soil is such that driving is easy or large number of piles of predetermined length are to be provided or where reinforcement is required from considerations of lateral pressure or tensile steel is required to resist uplift, precast piles are advantageous. The quality of concrete in precast piles is better as they are cast above ground under controlled conditions and hence, such piles are sometimes preferred in aggressive soil (e.g. sulphates) conditions.

Precast concrete piles for small loads and short lengths can be square in cross-section with chamfered corners, while for longer length and heavier loads they are generally of octagonal or circular section. Sometimes hollow sections are also used which are filled with concrete after driving. The tips are pointed to facilitate driving. As the reinforcement in the pile is mainly to resist the handling stresses, this objective can also be achieved by prestressing. It can be either pre-tensioned or post-tensioned. Prestressed concrete piles are not widely used as they are rather expensive.

Pile Driving

Piles are commonly driven by means of a pile driver, basic elements of which are a frame and a hammer. The frame or trestle is generally of steel and has a pair of vertical guides, known as leaders within which the hammer is held. Mobile units are also available and are convenient when a large number of piles are to be driven.

The hammer could be a simple drop hammer or more efficient steam, air, diesel or hydraulic hammers. It the fall of hammer is due to gravity alone, it is known as single acting. If pressure is applied by steam etc., it is known as double acting.

Drop hammers weigh from 1000 to 5000 kg and fall through a distance of about 1 meter. As a rough rule, the weight of a drop or single acting hammer could be the same as the weight of the pile. For heavy piles, this would not be possible but for proper driving the hammer should weigh not less than a third of the weight of the pile. A cast steel helmet is placed over the top of the concrete pile with a resilient dolly on top to prevent the pile head from shattering under the impact of the hammer blow.

The resistance to pile driving is expressed in terms of number of blows per inch of penetration. Resistance of 6 to 8 blows per inch are specified for concrete piles.

If piles have to be driven through dense layers, jetting around the pile is resorted to in order to loosen the soil and ease penetration. If piling is planned to be done by jetting, it is preferable to insert an M.S. pipe of 50 to 75 mm in diameter at the centre of the pile while casting.

In saturated plastic clays, displacement of soil on account of driving of pile may cause heaving of adjacent area, and in such cases piles can be placed in holes made by augering.

Cast in-situ Concrete Piles

There are two types of concrete cast in-situ piles – driven and bored.

Driven Cast in-situ Piles

In this type of piles, a heavy sectioned metal tube, with a detachable metal shoe at the bottom, is driven into the ground by a drop hammer or any other type of hammer up to the required depth. Thereafter reinforcement is placed, if required, and concrete is filled into the tube and the tube simultaneously withdrawn leaving the shoe at the bottom. In another version, a thin steel shell is driven with the help of a mandrel, which is then withdrawn, reinforcement placed, if required, and concreting done, the shell being left permanently in the ground.\

Raymond concrete pile company has developed a thin steel shell pile, known as Raymond Pile. The casing pipes consist of either uniformly tapered or step tapered light corrugated steel tubes. An internal mandrel is used to drive the casing, the mandrel is then withdrawn and the shell filled with concrete.

In Franki piles, a concrete plug is formed at the bottom of the steel casing and by repeated hammering the pipe is thrust downwards into the ground. When the bearing stratum is reached, additional concrete is poured and the plug hammered out of the tube to form a bulb end. Then the reinforcement cage is lowered into the tube, concreted and the casing withdrawn.

Vibro pile uses a detachable steel or cast iron shoe with a steel tube casing. With the help of a hammer, the tube with the shoe on is driven to the required depth, reinforcement cage lowered, concreting done and the tube withdrawn leaving the shoe at the bottom of the pile. Simplex piles are also similar to this sort of arrangement.

Bored Cast in-situ Piles

In this system, a hole is bored into the ground, reinforcement (if required) lowered and concreting done. Boring is generally carried out by rotary or percussion type drilling rigs. Kelly mounted hydraulically operated grabs are also used.

If the soil is such that the walls of the bore would cave in, casing tubes have to be used which is subsequently extracted while concreting. Sometimes the casing is left in the ground and the concreting done within the casing. Such piles are known as cased piles. Another method to keep the sides of the hole in position is by pumping bentonite slurry into the borehole as the soil is removed. Bentonite is a clay of the montmorillonite group. Its slurry forms a membrane along the walls of the bore hole and also acts hydrostatically to retain the stability of the sides of the hole. After the required depth of the bore is reached a high slump concrete is placed by means of a tremic.

For piles of small diameter and depths upto 10 m, the minimum cement content of the concrete should be 3.5 kN/m^3 while for larger diameter and deeper piles it should be 4 kN/m^3. Slump of concrete shall range between 100 to 180 mm depending on the manner of concreting.

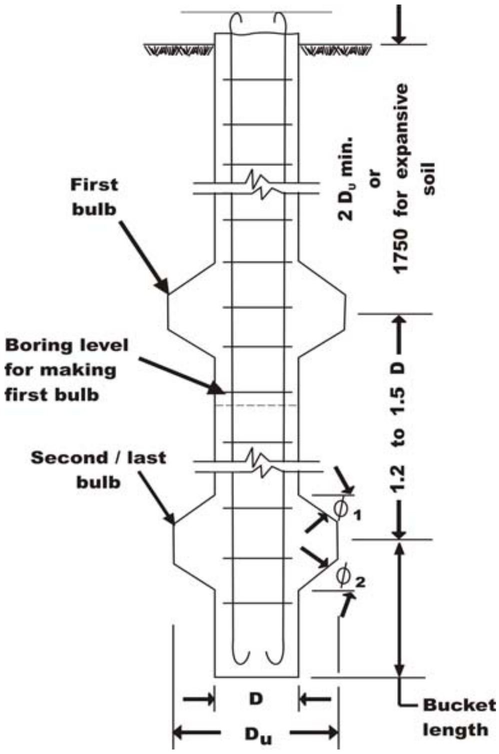
Where drilling mud is used before concreting, the bottom of the hole shall be flushed with fresh bentonite slurry. Throughout the boring operation, it has to be ensured that the drilling mud suspension is of the required consistency.

Underreamed Piles

These are bored cast in-situ concrete piles having one or more bulbs formed towards the bottom by enlarging the bore hole of the pile stem. The enlargements help in providing substantial bearing or anchorage. Such piles have been found to be useful in expansive soils like black cotton soil as the bulbs provide anchorage against uplift due to swelling pressures. The diameter of the underreamed bulbs may be of the order of 2 to 3 times the stem diameter. The spacing of the bulbs is 1.25 to 1.5 times the stem diameter. The top most bulbs should be at a minimum depth of 2 times the bulb diameter.

Boring for the piles are carried out in the usual way. Thereafter the bulbs are formed by means of an underreamer rotated by the drill rod. The excavated soil is removed by means of buckets. The reinforcement cage is then lowered and the pile concreted. The cement content and slumps shall be as indicated for bored cast in-situ piles.

Bored compaction pile is a modified form of underreamed pile where, after the concrete is poured, the reinforcement assembly, with a cone welded at the bottom is driven through the fresh concrete with the help of a driving pipe, thereby compacting the concrete.



$\phi_1 = 45^o$ approx, ϕ_2 = 30 to 45^o approx, D_u = Normally 2.5 D

All dimensions in mm

Figure 1.17 : Section of Underreamed Piles

Composite Piles

When you have a situation when the upper portion has to project above water, steel and concrete or wood and concrete piles can be used. Lower portion below water can be either of timber or steel while the upper portion can be of concrete.

Driven Piles

Preformed units usually in timber, concrete or steel are driven into the soil by the blows of a hammer.

Driven and Cast-in-situ Piles

These are formed by driving a tube with a closed end into the soil and filling the tube with concrete.

Jacked Piles

Steel or concrete piles jacked into the soil.

Bored and Cast-in-place Piles

Bored and cast in place piles are formed by boring a hole into the soil and then filled with concrete.

Displacement Piles

The disturbance to the soil during installation varies with the method. The driven piles and jacked piles displace the soil as they are installed and are called Displacement Piles. In loose sands, the displacement may compact the soil and increases the strength; however in stiff clay, such installation may crack the soil and reduce the strength.

Non-Displacement Piles

Bored piles are 'Non-displacement' piles since soil is first removed by boring a hole into which concrete is placed. Frictional resistance is normally reduced by boring operation.

Spacing of Piles

Spacing of piles has to be decided taking into consideration the practical aspects of installing the pile and the type of load transfer from the pile to the soil. For end bearing piles the minimum spacing is kept as 2.5 times the diameter of the shaft and if it is resting on rock it can be 2 times the diameter. The spacing between friction piles has to be such that the zones of soil from which the piles derive their support do not overlap and thereby reduce their bearing values. Generally, in such cases the minimum spacing is three times the diameter of the shaft.

Alignment of Piles

Piles shall be installed as accurately as possible. Generally, for vertical piles the permissible deviation is 1.5% and for raker piles 4%. The deviation from the designed position for a single pile should not be more than 50 mm (100 mm if diameter is more than 600 mm) and for each pile in a group not more than 75 mm or one tenth the diameter of the pile, whichever is more.

Load Testing of Piles

Load testing of piles consists of two types. Initial load test is done to determine the ultimate load carrying capacity and to arrive at the safe design load on the pile. It also helps to fix guidelines for routine tests, assess the suitability of the piling system, and to study the effect on existing adjacent structures etc. The second type of test is the routine test to check whether the pile is capable of carrying the designed load. Such tests are usually carried out on ½ to 2% of the total number of piles at the site, for a test load of one and a half times the working load, maximum settlement shall not exceeding 12 mm.

Piles are loaded by jacking against a kentledge placed on a platform supported clear of the test pile or against a beam restrained by anchor piles. Settlements of the pile are recorded by dial gauges carried by supports clear of the pile and resting on arms fixed rigidly to the pile head.

There are two methods of applying test loads. In the Constant Rate of Penetration (CRP) test, the load is adjusted to give a constant rate of downward movement. In the Maintained Load (ML) method, the load is applied in increments and deflections recorded. The CRP test is suitable for determining the ultimate load, while the ML method can be used for both initial test and routine tests.

Pile Caps

The depth of the pile cap should be sufficient for anchoring the column reinforcement as well as that of the pile. The pile should project 50 mm into the concrete of the cap. The cap should be rigid enough to distribute the load to the pile and to take care of differential settlements, if any. The overhang of the pile cap beyond the outer pile is of the order of 100 to 150 mm. The cap is generally cast over a 75 mm thick bed of levelling concrete. A clear cover of 60 mm is provided for the main reinforcement.

1.10.2 Pier Foundations

Pier foundations are used when the loads to be transmitted are heavier than loads those can be accomplished by piles. They are essentially bearing in nature and are not slender. They are constructed by making large shafts. In large sized piers, it may also be possible to inspect the strata before concreting the shaft. Drilled piers are constructed by drilling large diameter holes and are particularly suited in dry soils where a firm stratum of rock can be met with reasonable depths (Figure 1.18).

Figure 1.18 : Pier Foundation

1.10.3 Well Foundations

Well foundations are used to transmit large loads from piers of bridges and other marine structures. These are constructions carried out at site and are essentially bearing in nature. They are generally constructed by making circular concrete or masonry rings with steel cutting edge and then sunk into the ground by loading at the top. The sinking is facilitated by removing soil from inside. The side (steining) is then built up gradually till the bottom of the well reaches the required depth. The bottom is then plugged. The load is carried to the soil through the bottom of the well.

1.10.4 Caisson Foundations

Caisson foundations are similar to wells, but are much large in size. They are of different types, closed end, open ended and of pneumatic type. Figure 1.19 shows the different types of caissons.

Figure 1.19 : Caisson Foundations

1.11 DESIGN OF FOUNDATIONS

The basic purpose of foundation design is to ensure that the foundation is strong enough to resist all types of loads which are likely to come during the design life of the structure. It is, therefore, essential to assess the design load first before the detailed design. The loads coming on the foundation of a structure are dead loads, live loads, and wind loads.

Dead Loads

It consists of the self weight of the structure, weight of its footings, foundation and other permanent loads on the structure. It can be calculated by multiplying the volume with weight per m^3 of material.

Live Loads

It consists of moving or variable loads like that of people using the structure, temporary stores etc. Live loads are considered as uniformly distributed dead loads on the plain area of the floor or roof and it also includes the effect of normal impact.

Wind Loads

Wind acts horizontally on the exposed vertical surfaces of wall and inclined roof of the structure. Wind exert uniform pressure which tends to disturb the stability of the structure. While designing a structure and its foundation, separate as well as combined effect of imposed loads and wind loads are considered. Here, we will discuss about the design of wall foundation.

1.11.1 Design of Wall Footing

The design of wall footing comprises determination of following :

(a) the depth up to which the foundation of a structure should be taken below the ground level,

(b) depth of the concrete bed block, and

(c) the width of foundation.

Depth of Foundation

The minimum depth of foundation (*D*) can be determined by Rankine's formula

$$D = \frac{q}{r}\left(\frac{1 - \sin\,\phi}{1 + \sin\,\phi}\right)^2$$

where, D = minimum depth of foundation,

q = gross bearing capacity,

r = density of soil, and

ϕ = angle of repose of soil.

Depth of Concrete Bed Block

It depends upon the

(a) type of concrete used,

(b) projection of the concrete block beyond the bottom most, course of wall footing, and

(c) upward pressure of the soil below.

The concrete bed block may fail by shearing, crushing or by bending. The depth of concrete bed block is determined from the consideration of maximum bending moment and the depth thus obtained is found to render the concrete block safe against shear or crushing.

Let d = depth of concrete block in m.

J = projection of concrete block on either side of the lower most course of wall footing in metre,

m = safe modulus of rupture of concrete mix used in kN/m^2, and

p = load on foundation in kN/m^2.

Consider the cantilever projection *AB* of the concrete block.

Bending moment, *M*, about a vertical plane through *B*,

$$M = \frac{pj^2}{2} \text{ kN - m}$$

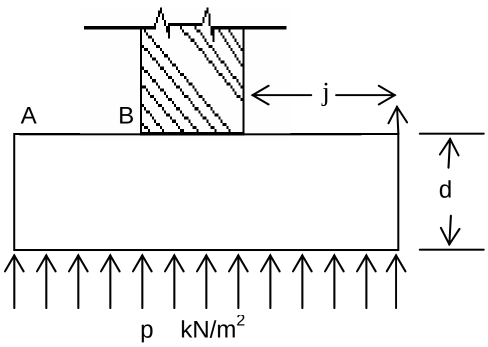


Figure 1.20

The moment of resistance of the concrete block

$$= \frac{md^2}{6} \text{ kN - m}$$

Equating the maximum bending moment with moment of resistance, we get

$$\frac{pj^2}{2} = \frac{md^2}{6} \Rightarrow d = \sqrt{\frac{3pj^2}{m}}$$

Width of Foundation

It is obtained by dividing the total load per unit length on the foundation bed by the safe bearing capacity of the soil.

Let w = total load in kN per m, and

q = safe bearing capacity in kN/m^2.

$\therefore$ Width of foundation $= \frac{w}{q}$ m . . . (1.1)

In order that the wall may be stable, the lowermost course of the wall footing is made twice the width of the wall (T) and the concrete bed block is made to extend at least (j) 10 to 15 cm on either side of the lowermost course,

Hence, the width of foundation

$$= 2T + 2j \qquad \text{. . . (1.2)}$$

The maximum value obtained from Eqs. (1.1) and (1.2) should be adopted as the final width of foundation.

1.12 SUMMARY

The first step in deciding on the type of foundation is to carry out a detailed soil investigation to ascertain the characteristics of the subsoil. Field tests of soil can also be carried out for quicker results. On the basis of these tests and investigations, the depth of foundation can be arrived at and the safe bearing capacity of the soil can be estimated. Taking into consideration the properties of soil substrata and the load due to the proposed building, it should be possible to decide on the type of foundation that would be suitable.

The details of shallow foundations such as pad, strip, grillage and raft have been described in the unit. If the soil in the top layer, near the ground, does not have adequate bearing capacity to support the superimposed load, it would be necessary to adopt pile foundations. The details of various types of pile foundation have also been explained in this unit.

Towards the end of the unit, design of wall footing has been discussed.

After being acquainted with the foundations, we will try to understand the details of superstructure, i.e. structure above the ground level in the next unit.

1.13 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section 'Further Reading' given at the end to get the answers of the SAQs.

UNIT 2 SUPERSTRUCTURE

Structure

2.1 INTRODUCTION

Superstructure of a building consists of the walls and framing above the foundations. The structural elements which transmit the loads of the building to the foundation can consist of load bearing walls or framed construction with infill (non-load bearing) walls. Structural framework can be either of steel or reinforced cement concrete (RCC) construction.

In this unit, we shall deal with walls, materials used for their construction and other relevant details.

Objectives

After studying this unit, you should be able to

- differentiate between various types of walls,
- familiarize yourself with the materials used in such a superstructure,
- explain various classifications and constructional details of brick, stone and block masonry,
- describe various types and constructional features of partitions walls, retaining walls, cavity wall and piers, and
- explain the importance of workmanship and quality assurance in masonry construction.

2.2 WALLS

Let us first try to analyse the various functions served by walls in a building.

(a) Walls support loads of upper floors and roof (in case of load bearing walls).

(b) Exterior wall of a building has to give protection against natural elements like sun, wind, rain, snow etc.

(c) Ground floor wall has to resist dampness also.

(d) They provide enclosure for ensuring security and privacy.

(e) Walls provide support for doors and windows.

(f) Walls provide thermal insulation.

(g) Walls provide sound insulation.

(h) Walls offer adequate resistance to fire.

(i) Walls serve as a base for suitable aesthetic treatment.

Walls can be constructed in various ways using a variety of building materials. The common materials used for construction of walls are as follows :

(a) bricks,

(b) stones, and

(c) various type of blocks.

The details of materials and construction practices of walls built from these materials are described in subsequent sections.

2.2.1 Partition Wall

The space inside a building has to be subdivided into rooms to serve different functions. This is carried out by partition walls. It ensures privacy, and may also provide insulation against heat and sound. Openings with door leaves are provided in these partitions for giving access. The partitions can be permanent or sometimes, as in offices, it may be desirable to have a system of internal divisions, which can be shifted to suit the possible changes in the use pattern of the spaces. They could be folding or sliding type also. They normally extend from the floor to the ceiling, but in some offices low partitions are used to afford a limited degree of privacy. They could be solid, hollow or louvered. Partitions can be opaque, transparent or translucent. Internal load bearing walls also serve the purpose of partitions. Non-load bearing partitions can be constructed from a wide variety of materials. The choice would depend on a number of factors such as thickness, weight, sound insulation, cost, ease of construction, necessity to shift, decorative treatment and fire resistance. For support of non-load bearing partitions, like for half brick masonry, there should be adequate structural arrangement.

Types of Non-load Bearing Partitions

Partitions can be divided broadly into two categories :

(a) Made from blocks and slabs laid in suitable mortar.

(b) Made of boards, sheets etc.

Under the first category fall partitions made from bricks, cement concrete blocks, burnt clay blocks, gypsum blocks etc. These are normally self-supporting if confined within permissible spans and heights. The latter category consists of several types of construction made of wooden panels, plywood, gypsum board, lath and plaster, hard and soft fibre boards, metal sheets etc. These partitions are framed with timber, metal or concrete frames, the sheets being fixed to one or both sides by means of screws, nails, clamps or other means. Alternatively, these partitions can be of build-up construction type fabricated in factories.

Brick Partition

These are constructed to half brick thickness by laying the bricks as stretcher. The mortar can be of lime or cement. Generally, the mortar used is sand cement mortar of 1 : 3 or 1 : 4 mix. The walls are plastered on both sides. For added strength, reinforcement can be provided as indicated in the section on reinforced brickwork. This type of partition is extensively used in buildings and is easy to construct along with the brickwork in the rest of the building. It has a good sound insulation and fire resistance properties. The earlier practice of providing timber frames called nogging and constructing the brickwork within is now not popular.

Block Partitions

This can be built from the various types of blocks, described later in this unit, in suitable mortar and is generally 10 cm wide. The distance between supports for these partitions in the vertical or horizontal direction whichever is smaller should not be more than 48 times the thickness of the blocks. If required, reinforcement, as in reinforced brickwork, can be provided and both sides plastered. Hollow burnt clay blocks can also be used for partitions. They are comparatively lighter being only about 40 to 50% the weight of a solid brick wall of same thickness and provide good sound insulation. Other materials like gypsum block, wood wool slabs etc. are also used. Glass blocks can be used where light is required to come in. Glass blocks of various sizes and shapes are available. Generally, they are hollow. It has to be ensured that no other load than self-weight comes on these partitions. The blocks can be laid in cement lime mortar (1 : 1 : 4). If blocks are larger than 30 cm, the joints are reinforced with hoop iron or expanded metal strips. It has an attractive appearance, can be easily cleaned and has good sound insulation properties.

Partitions of Sheeted Materials

The conventional timber partitions known as *stud partitions* are constructed of 100 × 75 mm heads and sills with vertical members or studs of 75 × 38 mm or 100 × 50 mm framed at about 400 mm centres (Figure 2.1). Horizontal timber members known as noggings of size 100 × 38 mm. Timber boards are nailed on both sides of the frame and painted or polished stiffen the studs.

Other sheets like gypsum plasterboard, fibre building board, plywood, particle board, blocks board, AC sheet, GI sheet etc., can also be used with a timber frame. The details of spacing of supports and the spacing of nails for some of the commonly used sheets are given in Table 2.1.

Table 2.1 : Spacing for Support and Fixing of Rigid Wall Board

Sl. No.	Type of Board	Thickness (mm)	Spacing of Supports (mm)	Nail Spacing c/c (mm)		Min. Edge Clearance of Nails (mm)
				At Edges	At Supports	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	Gypsum Board	9.5 12.5 15	400 500 600	100 to 150	100 to 150	10
2.	Fire Building Board, Particle Board etc.	10 12 20	400 500 600	75	150 to 200	10
3.	Plywood, Block Board etc.	6.9 12 16	400 500 600	150	300	10
4.	Asbestos Board	6	400	150 to 200	150 to 200	

Note :

(a) Nails with shank diameter 2, 2.34 or 2.50 mm are commonly used.

(b) Joint thickness shall be of 6 mm. All vertical joints shall be staggered, particularly when both sides of the wall are covered.

All portions of timber built into or against masonry or concrete shall be given two coats of boiling coal tar. All wood work shall be painted with approved wood primer.

The framework for fixing the sheets can also be of light steel sections.

Partitions with sheets are light in weight and hence, can be put up directly over slabs. They are easy to install and can be dismantled without any difficulty.

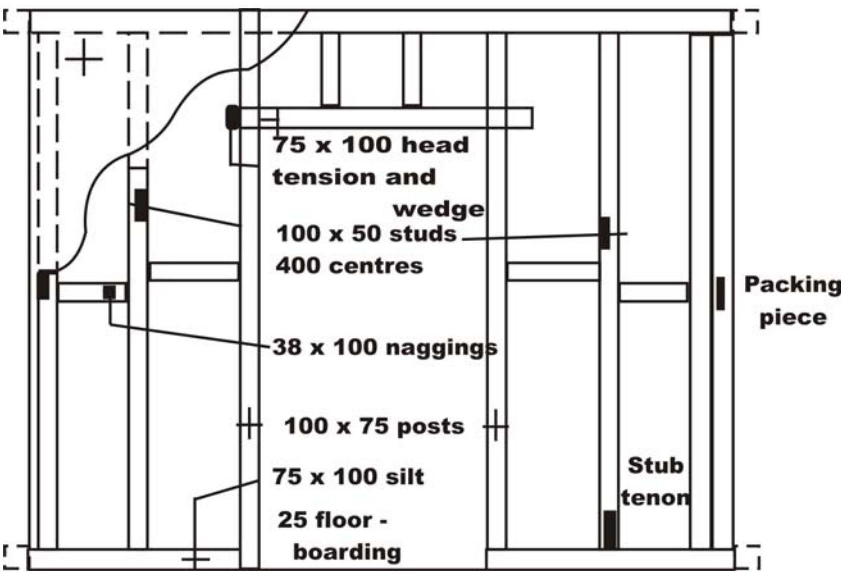


Figure 2.1: Timber Partitions (All Dimensions are in mm)

SAQ 1

Explain in detail how you would proceed with the construction of plywood partitions in an office building?

2.2.2 Retaining Wall

Retaining walls are structures which helps in maintaining the surface of the ground at different elevations on either side of the structure. If the retaining wall was not there, the soil at higher elevation would tend to move down till it acquires its natural, stable configuration.

Consequently the soil that is now retained at a steeper slope than it can sustain by virtue of its shear strength exerts a force on the retaining wall. The different types of retaining walls are as follow :

(a) Gravity walls

(b) Cantilever walls

(c) Counterfort walls

(d) Buttress walls

(e) Crib walls

(f) Gabion wall

(g) Sheet pile walls

(h) Anchored earth walls

(i) Diaphragm walls

(j) Reinforced earth walls

A brief description of each wall is given in below.

Gravity Walls

This wall depends on its self-weight for its stability. It is designed so that the overturning effect of the lateral earth pressure does not induce tensile stresses within the section. This is used for walls of low height and is not economical for large heights. Gravity walls have been built of stone, bricks, mass concrete and precast concrete blocks.

The cross section of the wall is trapezoidal with a base width between 0.3 and 0.5 H, where H is the height of the wall. The top width varies from 0.2 to 0.3 m. For concrete, a top width of 0.3 m is recommended for proper placement of concrete.

Cantilever Walls

Reinforced concrete cantilever retaining walls are suitable for heights up to 7 m. It has a vertical stem monolithic with the base. The slender sections are possible as the tensile stresses within the stem and the base are resisted by steel reinforcement. If the face of the wall is to be exposed a small backward batter of about 1 in 50 is provided in order to compensate for any forward tilting of the wall as shown in Figure 2.2.

Figure 2.2 : Cantilever Wall

Counterfort Wall

These walls are used for heights greater than about 6.0 m. Its wall stem acts as a slab spanning between the counterfort supports. The spacing between supports is about 2/3 H but should not be less than 2.5 m. Details of the walls are given in Figure 2.3.

Figure 2.3 : Counterfort Wall

Buttress Walls

A form of counterfort wall is the buttressed wall where the counterforts are built on the face of the wall and not within the backfill. These walls are not very popular because of the exposed buttressed which consume space and spoil the appearance.

Crib Wall

The crib wall is shown in Figure 2.4. It consists of a series of boxes made from timber, precast concrete or steel members, which are filled with granular soils. It acts as a gravity wall with the advantage of quick erection.

Figure 2.4 : Crib Wall

It can also withstand relatively large displacements due to its flexible nature. It is usually fitted so that its face has a batter of 1 in 6. The width of the wall varies from 0.5 to 1.0 H and is suitable for walls up to a height of

about
7.0 m. Note that the crib wall should not be subjected to surcharge loadings.

Gabion Wall

A gabion wall is built of rectangular metal cages or baskets. They are made from a square grid of steel fabric, generally 5 mm in diameter and spaced 75 mm apart. These baskets are usually 2 m long and 1 m in cross section. A central diaphragm fitted in each metal basket divides it into two equal 1 m × 1 m sections and adds stability. During construction the stone filled baskets are secured together with steel wire of 2.5 mm diameter. The base of the gabion wall is about 0.5 H. A typical wall is illustrated in Figure 2.5. A front face batter can be provided by slightly stepping back each succeeding layer.

Figure 2.5 : Gabion Wall

Sheet Pile Walls

These walls are made up from a series of interlocking piles individually driven into the foundation soil. Most modern sheet pile walls are made of steel. Sometimes timber or precast concrete sections are also used.

Cantilever sheet pile walls are held in the ground by the active and passive pressures that act on its lower part (Figure 2.6).

Figure 2.6 : Sheet Pile Wall

Anchored Earth Walls

Anchored sheet piles walls are fixed at the base and are supported by a row or two rows of ties or struts placed near its top.

Diaphragm Walls

A diaphragm wall can be classified either as a reinforced concrete wall or sheet pile wall. It consists of a vertical concrete reinforced concrete slab fixed in position. It is held in position by the passive and active pressures acting on its lower portion.

A diaphragm wall is constructed by a machine digging a trench in panels of limited length filled with the bentonite slurry as the digging proceeds to the required depth. In clays there is no penetration of bentonite slurry into the soil. But in sands and silts, bentonite slurry initially penetrates into the soil and creates a virtually impervious skin of bentonite particles, only a few mm thick, on the sides of the trench. The lateral pressure created by slurry acts on the sides of the short trench panel and prevents its collapse. The required steel reinforcement is lowered into position when excavation is complete. The trench is then filled with concrete by means of a tremie pipe, the displaced slurry being collected for cleaning and further use.

A wall is constructed in alternating short panel lengths. When the concrete has developed sufficient strength, the remaining intermediate panels are excavated and constructed to complete the walls. The various construction stages are shown in Figure 2.7.

(a) (b) (c) (d)

Figure 2.7 : Diaphragm Wall; (a) Trench Dug, (b) Reinforcement Insert, (c) Concrete Displaces Bentonite and (d) Soil Excavated in Front of Wall

Reinforced Earth Walls

The use of reinforcement to strengthen the soil has been known for centuries. Straw has been used to strengthen unburnt bricks and fascine mattresses have been used to strengthen soft soil deposits prior to road construction. The principle of reinforced earth is that a mass of soil can be given tensile strength in a specific direction if lengths of a material capable of carrying tension are embedded within it in the required direction. A rational approach to the design of reinforced earth was presented by Vidal in 1966. Reinforced earth has been used in many geotechnical applications. Here, we are only concerned with retaining structures.

A reinforced earth wall is a gravity structure. A simple form of such a wall is illustrated in Figure 2.8. The components listed are described below :

Figure 2.8 : Reinforced Earth Walls

The soil fill should be granular and free draining. The reinforcing elements can be either metal strips or geosynthetics. This metallic strips, 50-100 mm wide and 3 to 5 mm thick, are generally used. Metal grids have also been employed in some cases. Galvanised steel strips are the most common reinforcement. Aluminium alloy, copper and stainless steel are the other metals used. All these materials have a high modulus of elasticity and negligible strains are created within the soil mass.

There have been increasing use of geosynthetics as reinforcement in reinforced earth from 1975. Woven geotextiles and geogrids have the advantage of greater durability than metals in corrosive soil. Their tensile strength can approach that of steel. Geogrids can achieve high frictional properties between itself and the surrounding soil. However, all the geosynthetics undergo creep deformation under sustained loading which can lead to large strains within the soil mass.

At the boundary of reinforced earth structure it is necessary to provide a facing so that fill is contained. The facing does not contribute to the structural strength of the wall. The facing is usually built up from prefabricated units small and light enough to be handled by manual labour. The most common facing material is precast concrete though steel, aluminium and plastic units have been used. A concrete foundation is required to form a platform from which facing units can be built up.

Reinforced earth can provide a satisfactory method for retaining soil when existing conditions do not allow construction by conventional methods. A compressible soil may be capable of supporting a reinforced earth structure while pile foundation may be required in the case of gravity or cantilever walls. The technique can also be used when there is insufficient land space to construct the sloping side of an earthen embankment.

Please note that in developed countries reinforced earth is often the first choice for design engineers when considering an earth retaining structure.

2.2.3 Cavity Wall

A cavity wall consists of two walls with a cavity of 5 to 8 cm between them. The outer wall consists of a 100 mm thick wall and the inner wall is sufficiently thick and strong to carry the imposed loads safely. The minimum thickness of the inner wall is restricted to 100 mm.

A cavity wall have the following advantages :

(a) The provision of a continuous cavity in the wall efficiently prevents the transmission of dampness to the inner wall.

(b) Cavity walls have good sound insulation property.

(c) Construction of cavity walls are economical.

(d) There is no possibility of the moisture travelling from the outer leaf to the inner leaf because there is no intimate contact between the two leaves except at the wall ties.

(e) Cavity walls have 25% greater insulating value than solid walls.

(f) Cavity walls are best suitable for a tropical country like India.

The following points should be kept in mind during construction of a cavity wall :

(a) The contact between the inner and outer wall should be avoided.

(b) During construction, necessary precautions are required to be taken so that no mortar or any other thing should get accumulated in the cavity.

(c) The horizontal damp proof course should be built in two separate widths under each leaf of the wall and divided by cavity.

(d) The cavity should be free from any projections.

(e) The heads of openings should be carefully attended for damp prevention whenever doors and windows are provided in the wall.

(f) Ties should be able to prevent transmission of water from inner face to the outer face and it must be of rust proof material.

2.2.4 Piers

It is a vertical member generally constructed of stone or brick masonry to support an arch, beam or lintel etc., the width of which exceeds four times its thickness. The piers are made monolithic with the wall for the purpose of increasing the stability and stiffness of the wall to carry more concentrated loads.

Brick piers are generally built in either English Bond or Double Flemish Bond. The main function of brick piers attached to main walls is to provide a large bearing area for giving support to the roof. It also helps in increasing the stability of the wall by stiffening it at intermediate points along the length of the wall.

2.3 DEFINITION OF THE TERMS

Header

It is a full brick or stone, which is laid with its length perpendicular to the face of the wall. This denotes the end of a brick as seen in the wall face measuring 9 cm.

Stretcher

It is a full brick or stone, which is laid with its length parallel to the face of the wall. The side of a brick have seen in elevation in a wall, where the brick is laid flat measuring 19 cm × 9 cm.

Bed

It is the lower surface of the brick on which it rests.

Courses

A complete layer of bricks laid on the same bed is termed as course.

Header Course

It consists of only headers as seen in elevation.

Stretcher Course

It consists of only stretchers as seen in elevation.

Face

The surface of a wall exposed to weather is termed as face.

Joint

The junction of two or more bricks or stones is known as joint.

Bed Joints

Horizontal mortar joints between the two courses of bricks or stones are termed as bed joints.

Cross Joints

The joints which are perpendicular to the face of wall are termed as cross joints.

Closer

It is a portion of a brick cut longitudinally in such a way that its one long face remains uncut.

Frog

It is a depression on the top face of a brick provided to form a key for holding the mortar.

Quoin

The brick or wedge shaped stone used for the corner of walls is known as quoin.

Cornice

It is a projecting ornamental course near the top of a building or at junction of a wall and ceiling.

Throating

These are grooves cut on the under surfaces of a projecting course of masonry to prevent the water from trickling down the walls.

Templates

These are blocks of stone or concrete placed under the end of a beam or girder to distribute the load over a greater area.

2.4 BRICK MASONRY

Bricks are still one of the most popular materials for construction of walls on account of its ready availability, ease of handling and construction, and economy.

2.4.1 Bricks

Bricks are made from ordinary clay, moulded and burnt in kilns. They can be hand moulded or machine pressed or extruded and wire cut. They should be well burnt, of uniform colour, free from cracks and nodules of free lime. They have, generally, a depression on one flat face, known as a *frog*, which enables better keying of the mortar joint. Bricks are available in the traditional nominal dimensions of 22.9 × 11.4 × 7.5 cm (actual 22.5 cm × 11.1 cm × 7 cm) or modular nominal sizes of 20 cm × 10 cm × 10 cm (actual 19 cm × 9 cm × 9 cm).

The traditional brick sizes vary in different parts of the country with length from 21 to 25 cm, width 10 to 13 cm and height 7 to 7.5 cm. With a view to achieve uniformity of size throughout the country, the Bureau of Indian Standards standardized the modular size of bricks.

BIS Classification of Bricks

The BIS has classified the bricks into HI, HII, FI, FII, I, II, LI and LII categories, primarily according to the compressive strength. Table 2.2 gives the BIS classification of bricks.

Table 2.2 : BIS Classification of Bricks

Class of Bricks	Minimum Compressive Strength (kg/cm^2)	Minimum Absorption in 24 Hours in Percent of Dry Weight	Efflorescence	Tolerance in Dimension in Percent	Shape and Other Properties
HI	440	5	No	± 3	Metallic sound, smooth, rectangular
HII	440	5	No	± 8	Slight deformation in shape permitted.
FI	175	12	Very little	± 3	Smooth, rectangular, metallic sound when two bricks strike.
FII	175	12	Very little	± 8	Slight deformation in shape permitted
I	70	20	Very little	± 3	Smooth, rectangular, metallic sound when two bricks strike.
II	70	20	Very little	± 8	Slight deformation in shape permitted
LI	35	25	Very little	± 3	Rectangular, sharp edge, metallic sound on striking need not be present
LII	35	25	Little	± 8	Slight deformation in shape allowed.

In general bricks may be classified into five categories

(a) First class bricks

(b) Second Class bricks

(c) Third Class bricks

(d) Over burnt or Jhama bricks

(e) Under burnt or killa bricks

[**Note :** You may go through study material of Engineering Materials BET-015 for detailed information of above classification.]

Certain tests are necessary to be conducted for judging the quality of a brick lot. These tests are :

(a) Water absorption test

(b) Test for presence of soluble salts

(c) Crushing strength test

(d) Hardness test

(e) Shape and size test

(f) Soundness test

Water Absorption Test

There are two tests to determine the water absorption. These are

(a) 24-hour immersion cold water test, and

(b) 5-hour boiling water test.

24-Hour Immersion Cold Water Test

Dry specimen is put in an oven maintained at a temperature of 105 to 115°C, till it attains substantially constant mass. Weight of specimen (W_1) is recorded after cooling it to room temperature. The dry specimen is then immersed completely in water at a temperature of 27 ± 2°C for 24 hours. Take the specimen out of water and wipe out all traces of water with damp cloth. Complete weighing of the specimen 3 minutes after the specimen has been removed from water. Let this weight be (W_2).

Water absorption percent by mass, after 24 hours immersion in cold water is given by

$$\frac{W_2 - W_1}{W_1} \times 100$$

5-Hour Boiling Water Test

The specimen is dried in an oven at 105 to 115°C till it attains constant mass. Cool the specimen at room temperature and record its weight (W_1). The brick is immersed in boiling water for 5 hours. The water is allowed to cool at 27 ± 2°C with brick immersed. The brick is taken out and wiped with damp cloth. Complete the weighing of the specimen in three minutes. Let it be W_3.

Water absorption, percent by mass, is given by

$$\frac{W_3 - W_1}{W_1} \times 100$$

Test for Presence of Soluble Salts

Soluble salts if present in the brick cause efflorescence. Presence of such salts can be determined as follows :

Place on the ends the bricks in 25 mm depth of water in a dish of minimum diameter 150 mm and depth 30 mm. The dish is made of glass, porcelain or of glazed stone work. The experiment is performed in a well-ventilated room between "20 to 30°C" till all the water in the dish is either absorbed by the specimen or is evaporated. After the specimens have dried add similar quantity of water to the dish and let it too be absorbed by the specimen for efflorescence after the second evaporation. Presence of efflorescence shall be classified as nil, slight, moderate, heavy or serious as defined below :

Nil

When the deposit of efflorescence is imperceptible.

Slight

When the deposit of efflorescence does not cover more than 10% of the exposed area of the brick.

Moderate

When the deposit of efflorescence is heavier than slight and does not cover more than 50 percent of the exposed area of the brick surface. The deposit should not, however, powder or flake of the surface.

Heavy

When the deposit of efflorescence salts is heavy and covers 50 percent or more of the exposed area of brick surface. The deposit, however, does not powder or flake of the surface.

Serious

When the deposit of efflorescence salts is heavy and is accompanied by powdering and/or flaking of the exposed surfaces.

Crushing Strength Test

In this test well-burnt bricks areas elected. Grind the two bed faces to provide smooth, even and parallel faces. Immerse the specimen in water at room temperature. Fill up flush the frog and all voids with cement mortar (1 part cement and 1 part clean coarse sand of grade 3 mm and down), store under damp jute bags for 24 hours and then immerse in clean water for 3 days. Remove and wipe out any traces of moisture.

Place the specimen between two plywood sheets; each 3 mm thick, with flat faces horizontal and mortar filled face facing upwards. The specimen sand wiched between the ply sheets are carefully centred between plates of compression testing machine. Apply axial load at a uniform rate of 140 kg/cm^2 per minute till failure. The maximum load at failure divided by the average area of the bed faces gives the compressive strength.

Hardness Test

Hardness of the bricks can be estimated with the help of the scratch of the fingernail. If no nail scratch is left on the brick, it is considered to be having sufficient hardness.

Shape and Size Test

All the faces of the brick should be truly rectangular and size truly standard as specified by Indian Standards. All the edges should be sharp and right-angled.

Soundness Test

Soundness of the bricks is estimated by striking two bricks against each other. They should emit ringing sound. Soundness of the brick is also tested by the fall of the brick. A good sound brick should not break, when made to fall flat on hard ground from a height of about 1 m.

2.4.2 Mortars

There are many types of mortars used in brickwork. The type and mix of mortar has to be decided taking into account the strength required, and, the availability of materials and skilled labour etc. In general, the strength of the mortar shall not be greater than that of the masonry unit.

2.4.3 Materials

Water

Water used shall be clean and reasonably free from deleterious materials like oils, acids, alkalies, salts etc. Potable water is generally considered satisfactory. Water should be tested for the following characteristics :

Limits of Acidity

To neutralise 200 ml sample of water, it should not require more than 2 ml of 0.1 normal caustic soda solutions.

Limits of Alkalinity

To neutralise 200 ml sample of water, it should not require more than 10 ml of 0.1 normal hydrochloric acid.

Percentage of Solids

It shall not exceed the following limits for various solids :

Organic	200 mg/l
Inorganic	3000 mg/l
Sulphates	500 mg/l
Chlorides	2000 mg/l
Suspended matter	2000 mg/l

The pH Value

The pH value of water shall generally be not less than 6.

Cement

Cement shall conform to any one of the following specifications :

33 grade ordinary portland cement, IS : 269 – 1989

43 grade ordinary portland cement, IS : 8112 – 1989

53 grade ordinary portland cement, IS : 1269 – 1987

Rapid hardening portland cement, IS : 8041 – 1990

Low heat portland cement, IS : 12600 – 1989

Portland Pozzolana cement, IS : 1489 – 1991

Portland slag cement, IS : 455 – 1989

Lime

Lime shall conform to standards given in IS: 712 – 1984.

Building lime shall be classified as follows :

Class A – Eminently hydraulic lime used for structural purposes.

Class B – Semi-hydraulic lime for masonry.

Class C – Fat lime used for finishing purposes; it can be used for masonry mortar with addition of pozzolanic material.

Class D – Magnesium lime used for finishing coat.

Class E – Kankar lime used for mortar.

Carbide lime obtained as a byproduct in the manufacture of acetyline meets the requirement of class C lime and can be used for mortar.

Fine Aggregate

This consists of natural pit or river sand, or crushed stone, most of which passes through IS Sieve 4.75 mm. It shall not contain harmful organic impurities in such form or quantities (5%) to affect the strength of the mortar. Sand is generally classified as fine or coarse.

Fine Sand

This shall be river sand and the grading shall be within the limits of grading Zone IV of Table 2.3.

Table 2.3 : Grading of Fine Aggregate

IS Sieve Designation	Percentage Passing Grading				
	Zone I	Zone II	Zone III	Zone IV	Zone V
10 mm	100	100	100	100	-
4.75 mm	90-100	90-100	90-100	95-100	-
2.36 mm	60-95	75-100	85-100	95-100	100
1.18 mm	30-70	55-90	75-100	90-100	100
600 μ	15-34	35-59	35-60	80-100	85-100
300 μ	5-20	8-30	8-30	20-65	65-95
150 μ	0-10	0-10	0-10	0-15	0-60

Stone Dust

This shall be obtained by crushing hard stones and the grading shall be within the limit for Zone III of Table 2.3.

Coarse Sand

This shall be either river sand or pit sand and shall conform to the grading of Zone III of Table 2.3.

The silt or organic content in fine aggregate should not in any case exceed 8%. Placing a sample of sand in a 200 ml measuring cylinder tests the silt content. The volume of sample will be such that it fills up to the 100 ml mark. Clean water shall be added up to the 150 ml mark. Before adding water, dissolve a little salt (one teaspoon per half liter) in the water. Shake the mixture vigorously. Allow the contents to settle down for three hours. The height of the silt visible as a layer above the sand shall be expressed as a percentage of the height of sand below.

Sand having more than the allowable percentage of silt shall be washed to bring down the silt content within the specified limits.

Cement Mortar

This shall be prepared by mixing cement and sand in the specified proportion for the given work. For load bearing construction coarse sand is used in the mix of the mortar. The proportion of cement and sand in cement mortars varies generally from 1 cement to 3 to 8 of sand, the strength and workability improving with increase in the proportion of cement. Mortars richer than 1 : 3 are not used in masonry because of high shrinkage with no appreciable gain in the strength of the masonry. Mortars leaner than 1 : 6 proportion tend to become harsh and, hence, unworkable.

Lime Mortar

This consists of lime as a binder and sand, surkhi, cinder as fine aggregates, generally in the proportion 1 : 2 or 1 : 3. Lime is slaked and used as lime putty. Hydrated lime available in powder form can also be used. Lime mortar gains strength slowly. The main advantages of lime mortar are its good workability, high water retentivity and low shrinkage.

Cement Lime Mortar

This type of mortar has some of the advantages of both the types of mortars. It has medium strength along with good workability and water retentivity. Commonly adopted proportions are Cement : Lime : Sand of 1 : 1 : 6, 1 : 2 : 9 and 1 : 3 : 12. The mix proportion of binder (cement plus lime) to sand is kept as 1 : 3.

The mix proportion and compressive strength of some of the commonly used mortars are given in Table 2.4.

Table 2.4 : Mix Proportion and Strength of Commonly Used Mortars

Sl. No.	Mix			Min. Compressive Strength (N/mm^2)
	Cement	Lime	Sand	
(1)	(2)	(3)	(4)	(5)
1	1	0-1/4C	3	10
2(a)	1	0	4	7.5
2(b)	1	1/2C	4 .5	6
3(a)	1	0	5	5
3(b)	1	1C	6	3
4(a)	1	0	6	3
4(b)	1	2C	9	2
4(c)	0	1A	2-3	2
5(a)	1	0	8	0.7
5(b)	1	3C	12	0.7
6	0	1B or C	2-3	0.5

Note 1 : A, B, C, denote eminently hydraulic lime, semi-hydraulic lime, and fat lime respectively, as stipulated in IS 712 : 1984.

Note 2 : When using plain cement sand mortars (Sl. No. 2(a), 3(a), 4(a) and 5(a), it is desirable to include a plasticizer in the mix to improve its workability.

Note 3 : For Mortar at Sl. No. 6, if lime C is used, part of sand should be replaced by some pozzolanic material, for example, burnt clay or fly ash, in order to obtain the requisite strength.

Note 4 : Strength of a mortar may vary appreciably, depending on angularity, grading and fineness of sand. Quantity of sand in the mix may, therefore, be varied where found necessary to attain the desired strength.

Preparation of Mortar

For proportioning with cement mortar, the unit of measurement is a cement bag of 50 kg whose volume is taken as 0.35 cu m. While measuring sand, allowance shall be given for bulking (which is the phenomenon of increase in the volume of sand in the presence of moisture). The amount of bulking can be determined by making use of the fact that the volume of inundated sand is the same as that of the dry sand. To find bulking, pour the sand up to the 200 ml mark of a 250 ml measuring cylinder. Then fill the cylinder with water and stir well. It will be seen that the sand surface is now below its original level. Suppose the surface is at the mark – Y ml, the percentage of bulking is $\left[\frac{200 - Y}{Y}\right] \times 100$.

Table 2.5 : Relationship Between Moisture Content and Percentage of Bulking for Practical Guidance

Sl. No.	Moisture (%)	Bulking (% by Volume)
1.	2	15
2.	3	20
3.	4	25
4.	5	30

Mixing of mortar shall be preferably done in a mechanical mixer. Cement mortar shall be used within 30 minutes of mixing. Mixing lime putty, sand and surkhi and grinding it either manually or in a mechanical mortar mill generally make lime mortar. As a rule lime mortar shall be used on the same day it is made. For lime cement mortar, lime putty and sand shall be ground in a mill and the required quantity taken out and mixed thoroughly with the specified quantity of cement in a mechanical mixer.

In view of easy availability of cement, convenience in use, uniformity of quality and the difficulty in obtaining lime of good and consistent quality, as well as the cumbersome process of preparation of lime putty etc., the general practice in the country is to use cement mortar in masonry.

2.4.4 Brick Masonry

Construction Practices

Bricks are bedded in and jointed with mortar. The bricks are laid to any specific pattern known as bonds. The primary object of bond is to give maximum strength to the masonry and ensure equitable distribution of load. In bonded walls, the vertical joints of successive layers of brickwork are staggered and the pattern gives an attractive appearance to the wall face.

The various types of bonds used in brick masonry are as shown below.

Table 2.6 : Bonds in Brick Masonry

1.	English Bond	6.	Facing Bond
2.	Flemish Bond	7.	Raking Bond
3.	Stretching Bond	8.	Dutch Bond
4.	Heading Bond	9.	English Across Bond
5.	Garden Wall Bond	10.	Zig-zag Bond

The commonly used bonds are the English bond and the Flemish bond which are described below.

English Bond

The bricks in the facing are laid in alternate courses of headers and stretchers. The header course is commenced with a quoin header followed by a queen closer (which is a half brick cut longitudinally) and continued with successive headers. Stretchers having a minimum lap of one quarter their length over the header form the stretcher courses. Figure 2.9 shows details of the corner of a one brick wall and a one-and-a half brick wall and also a stopped end.

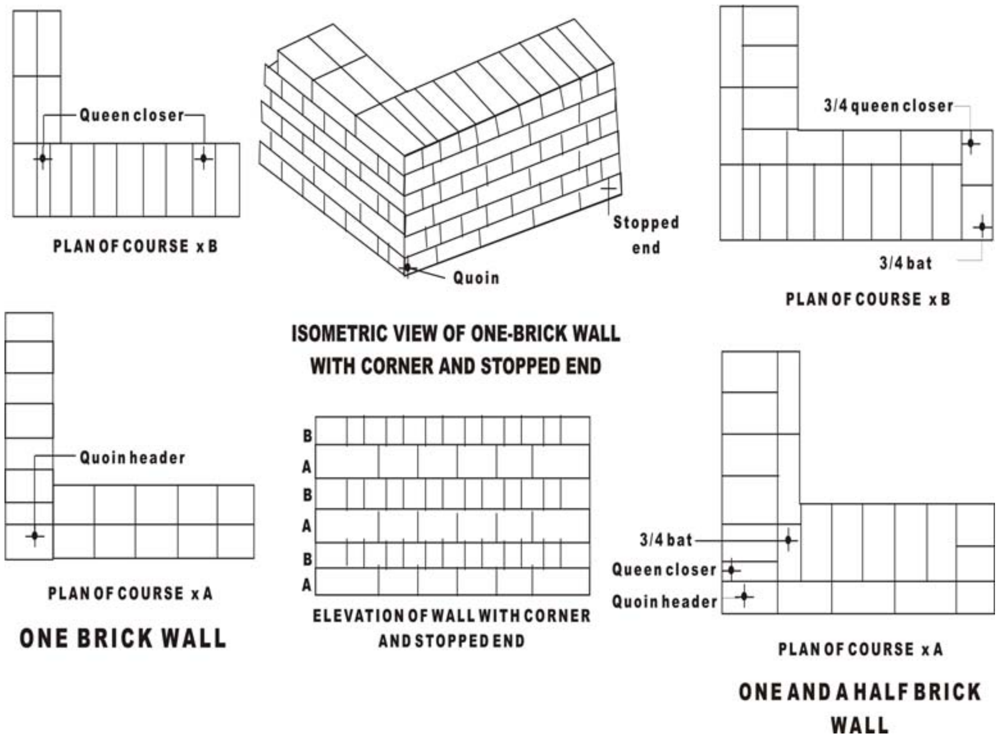


Figure 2.9 : English Bond

Flemish Bond

Bricks are laid as alternate header, and stretchers in the same course, the header in one course being in the center of the stretcher in the course above and below. In this bond, in addition to queen closer, a three-fourth brick bat has to be used. Figure 2.10 gives the details with a stopped end.

The choice of the bond depends on the situation, function, load and thickness of the wall. A Flemish bond gives an attractive appearance while an English bond is stronger. In our country, English bond is used widely for constructing brick masonry.

Construction

Bricks shall be adequately soaked in water before use. Wetting helps in removing dirt, dust and ash from the face of the bricks and in spreading of the mortar more evenly under the brick and also ensures better adhesion. It prevents absorption of water by the bricks from the mortar, which may cause decrease in its strength. The bricks shall be laid in courses according to the specific bond.

Bricks shall be laid on a full bed of mortar. Each brick shall be properly bedded by slightly pressing so that the brick surface is fully in contact with the mortar. All joints shall be properly flushed and packed with mortar so that no hollow spaces are left. Properly filled joints ensure strength of the masonry and resistance to penetration of moisture.

The thickness of joints shall not exceed 1 cm. All the face joints shall be raked to a depth of 15 mm during the progress of work when the mortar is still green to ensure proper keying of plaster or pointing. Where plastering or pointing is not to be done, the joints shall be finished flush at the time of laying.

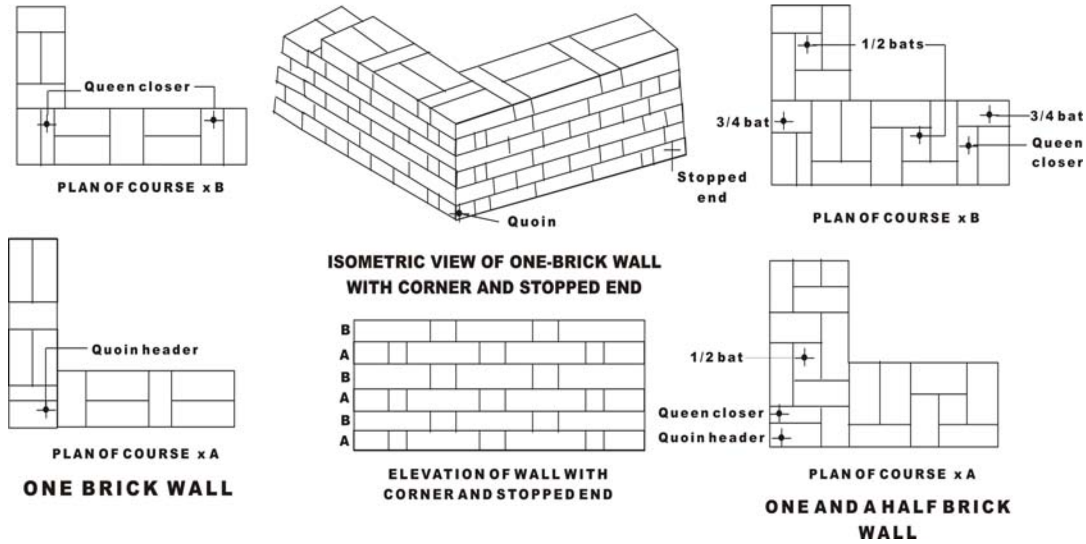


Figure 2.10 : Flemish Bond

Scaffolding

In order to construct masonry, scaffolding is used to facilitate the necessary movements of workers. Double scaffolding having two sets of vertical supports shall be used for all important works and also where exposed brick work is to be done. In single scaffolding, there is only one set of vertical supports and the wall under construction provides the other support. In such scaffolding, the placing of the poles on the brick work shall be so adjusted that they are on the header course, so that only one header is left out for each pole, which can subsequently be filled up with a full brick. Such holes shall not be allowed in pillars and columns less than one meter wide.

Curing

The brickwork shall be cured by constantly keeping it wet on all exposed faces for a minimum period of seven days.

All connected brickwork shall be taken up together and no portion of the work is left more than one meter below the rest of the work. Where this is not possible, the work shall be raked back, according to the type of bond being followed, in a series of steps at an angle not steeper than 45^o. Leaving such joints vertical with recesses or toothing in alternate layers should not be allowed as this will form a plane of weakness.

Cutting and Chasing

As far as possible services such as concealed pipes, conduits etc. should be planned with the help of vertical chases, while horizontal chases should be avoided. For load bearing walls, the depths of vertical and horizontal chases shall not exceed one-third and one-sixth the thickness of the masonry, respectively.

Verticality and Alignment

All masonry shall be built true and plumb within the tolerance limits specified below :

(a) Deviation in verticality in the total height of any wall of a building, more than one storey high, shall not exceed ± 12.5 mm.

(b) Deviation from the vertical within a storey shall not exceed ± 6 mm per 3 m height.

(c) Deviation from the position shown on the plan of any brickwork, more than one storey high, shall not exceed 12.5 mm.

(d) Relative displacement in load bearing walls in adjacent storeys intended to be in vertical alignment shall not exceed 6 mm.

(e) Deviation of horizontal mortar joints from the level shall not exceed 6 mm up to 12 m length, and for longer length shall not exceed 12.5 mm in total.

(f) Deviation from the specified thickness of horizontal and vertical joints shall not exceed ± 3 mm.

These tolerances are particularly relevant for load bearing walls.

2.4.5 Reinforced Brickwork

Plain brickwork is not capable of taking any tensile stress. By providing reinforcement of steel bars or flats or wire mesh the brickwork would be able to withstand some amount of tensile force. Such brickwork is known as reinforced brickwork. Good quality bricks having average compressive strength of 7.5 N/mm^2 and above and cement mortar not leaner than 1 : 4 is used in such a construction. Reinforced brickwork can be used in the construction of retaining walls. In half brick masonry, it is the general practice to provide at every third or fourth course, reinforcement consisting of two 6 or 8 mm dia bars or hoop iron of dimension 25 mm × 3 mm. Half the mortar for the joint is first laid, the reinforcement placed and the remaining mortar laid so that the steel is fully embedded in the mortar. Reinforced brickwork has the following advantages :

(a) Simplicity of construction.

(b) Good sound and permanent work involving very low repairing charges.

(c) Reinforced brick construction is fire proof.

(d) Neat and better appearance of the finished work.

(e) Cool rooms.

(f) It is cheaper than any other forms of pucca roofing.

SAQ 2

(a) What are the different functions served by walls in buildings?

(b) Describe the various tests to be carried out to ascertain the quality of bricks.

(c) Explain the purpose of providing a bond in the construction of a brickwork?

(d) When do you use reinforced brickwork? Explain the details of its construction.

(e) Discuss the class designation of bricks and cement : sand ratio of cement mortar suitable for reinforced brickwork.

2.5 STONE MASONRY

Stone masonry is a traditional form of construction in this country. However, in view of the ready availability of bricks and ease of constructing brickwork, the use of stone masonry is not very common.

Construction of stone masonry requires skilled masons, trained in dressing stones. Large irregular shaped stones have to be handled as compared to conveniently sized bricks or blocks. In hilly areas where stones are easily available and for prestigious buildings where the architects desire an elevation with stones, this type of masonry is still popular.

The common types of stone available in the country are granite, sandstone, limestone, basalt, marble etc. The strength of the building stone to be used shall be adequate to carry the imposed load. The crushing strengths of some of the types of stones are given below :

Type of Stone	Crushing Strength (N/mm^2)
Granite	100
Sandstone	30
Limestone	20
Basalt	40
Marble	50

The stones used in masonry shall be hard, sound, free from cavities, cracks, flaws, sandholes, veins, patches of soft or loose materials etc. The stone should not contain deleterious material like iron oxide and organic impurities. All stones should be wetted before use.

In selecting stones, the situation where this material is to be used has to be considered. Table 2.6 gives the recommended use of common types of stones :

Table 2.6 : Use of Common Types of Stones

Sl. No.	Situation	Types of Stone
1.	For carved ornamental work, arches, veneers etc.	Soft stones like marble, sandstone.
2.	For face work of building.	Granite, marble and close grained sandstone.
3.	Masonry work below plinth level and in subsoil water.	Dense stones like granite.
4.	Masonry work exposed to smoke or chemical fumes.	Granite, quartize.
5.	Fire resistant masonry.	Compact sandstone.

2.5.1 Types of Stone Masonry

The common types of stone masonry are listed and described below :

(a) Random rubble,

(b) Squared rubble,

(c) Coursed rubble, and

(d) Ashlar

Random Rubble

Uncoursed

Stones as obtained directly from the quarry are used, and are only hammer dressed on the face and sides so that they can be bedded properly with the adjacent stones (Figure 2.11).

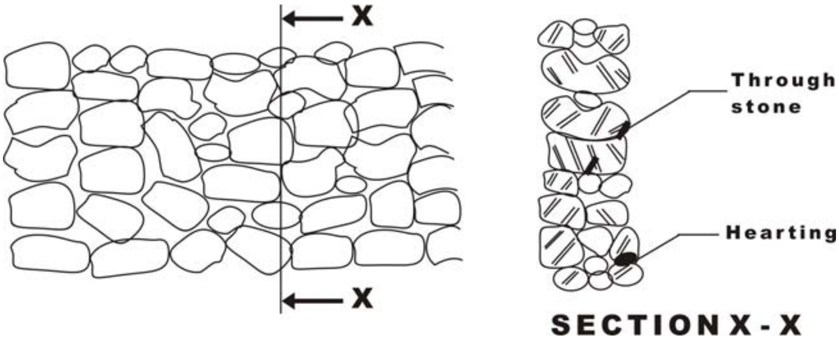


Figure 2.11 : Random Rubble Uncoursed Masonry

Normally, the size of a stone used is such that it can be lifted and placed manually. The length of the stone shall not exceed three times the height and the breadth on the base shall not be greater than three-fourth the thickness of the wall and not less than 15 cm.

The wall shall be taken up truly plumb. The stone work may be brought to course at the plinth, window sill and roof levels. The face stones shall extend and bond well into the backing. Work should be carried out in such a manner that the joints are staggered. The face joints shall not be more than 20 mm thick. Bond or through stones running right through the thickness of the wall shall be provided at the rate of one for every 0.5 m^2 of the wall area in order to tie the faces and strengthen the work. If the walls are thicker than 60 cms, instead of providing a single through stone, two stones one from each face – overlapping by at least 15 cm could be provided. The quoins or corner stones shall be selected stones, hammer dressed or chisel dressed and laid as headers and stretchers alternately.

Brought to Course

This is an improved version of random rubble masonry, except that the work is roughly levelled up to courses at intervals varying from 300 mm to 900 mm, according to the locality and the type of stone used (Figure 2.12).

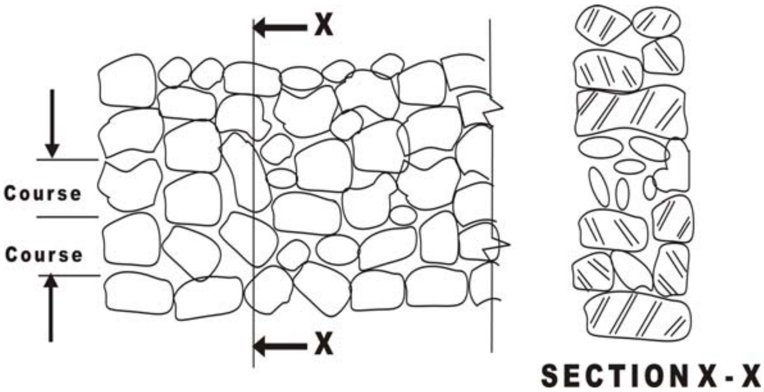


Figure 2.12 : Random Rubble Masonry Brought to Course

Squared Rubble

Uncoursed

In this type, the stones are roughly squared by hammer, and are laid as risers or jumpers and stretchers of varying height without bringing to course (Figure 2.13).

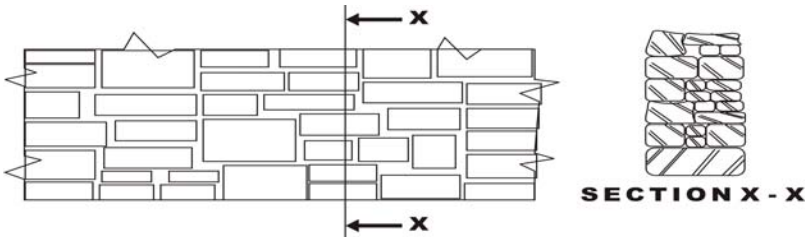


Figure 2.13 : Squared Rubble Uncoursed Masonry

Brought to Course

In this type, the work is levelled up to courses of varying depth from 300 to 900 mm (Figure 2.14).

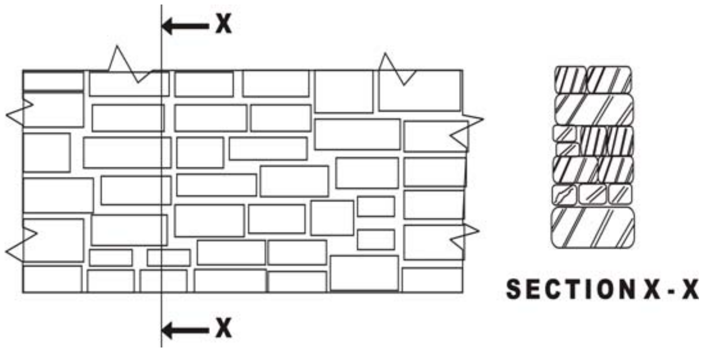


Figure 2.14 : Squared Rubble Masonry Brought to Course

Coursed Rubble Masonry

Ist Sort

The face stones shall be hammer dressed on all sides to give them approximately rectangular shape. These shall be squared on all joints and beds (Figure 2.15).

The bed joints are rough chisel dressed to a depth of at least 8 cms from the face and the side joints for at least 4 cms such that no portion of the dressed surface is more than 6 mm from a straight edge placed on it. The projections (or bushings) on the face stone shall not be more than 4 cms beyond the side or bed joint. The courses shall be laid as alternate headers and stretchers in horizontal layers and the side joints shall be vertical. The height of each course is normally between 15 cm to 30 cm. No face stone shall be less in breadth than its height and at least one third of them shall tail into the hearting to a length equal to twice their height. The hearting or the interior shall also consist of stones carefully laid on their beds. Chips can be used to fill the interstices but the quantity used should not exceed 10% of the stone masonry. Bond stones shall be provided in every course, the spacing being 1.5 to 1.8 m. The quoins shall be of the same height as the course and at least 45 cm long, laid as headers and stretchers. The beds of these stones shall be chisel dressed to a depth of 10 cm. Generally, quoins have a chisel draft 2.5 cm wide along the edges of the face. The face joints in the masonry shall not be more than 1 cm thick.

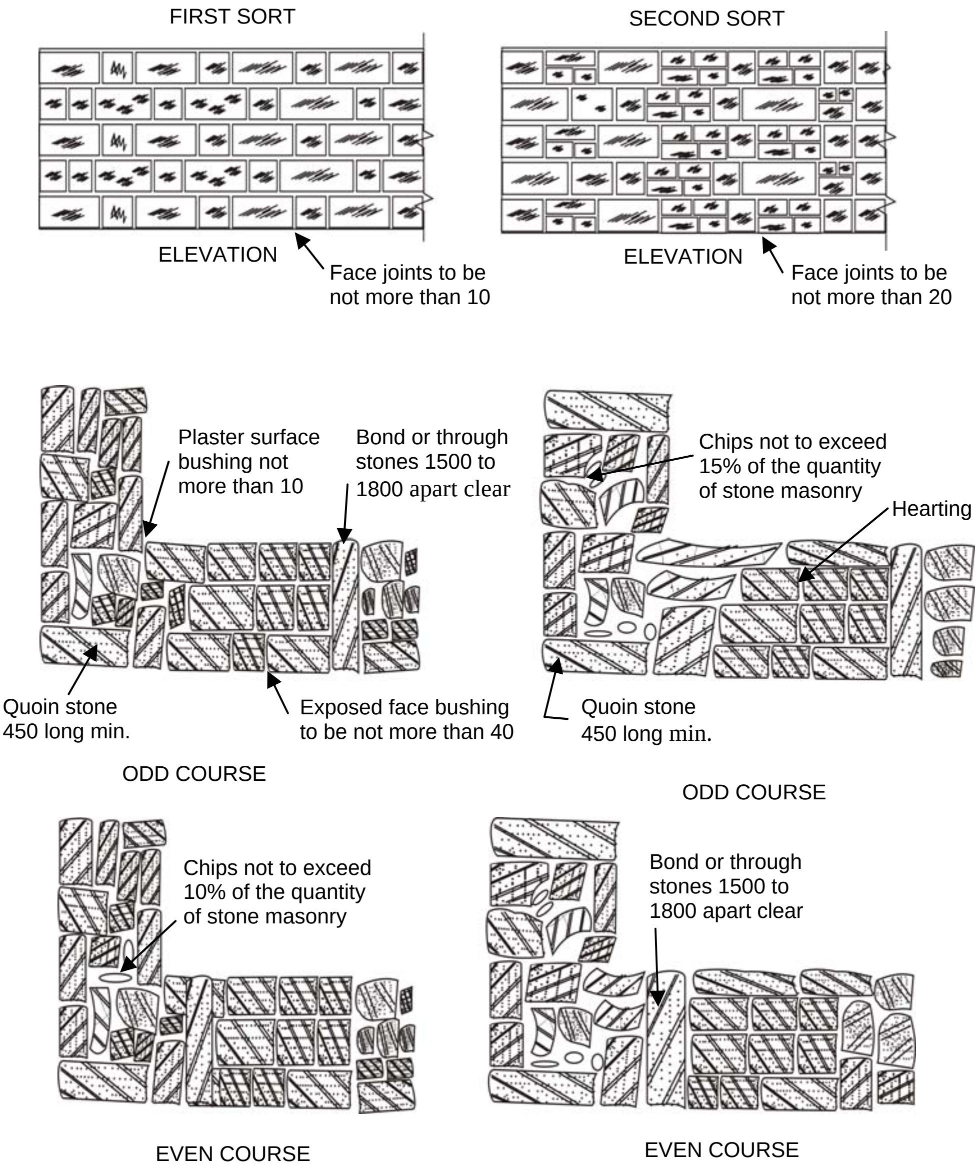


Figure 2.15 : Coursed Rubble Masonry (All Dimensions are in mm)

2nd Sort

This is similar to the work discussed earlier, except that the dressing of the joints could be rougher, with the deviation being 10 mm from a straight edge and the use of chips in the hearting could be 15%. Some of the stones in each course could be of half height so that two stones are used to make up the course. The face joints could be 2 cm thick.

Ashlar

Plain Ashlar

Each stone shall be cut to the required size and shape so as to be free from any distortion and to give truly vertical and horizontal joints (Figure 2.16). Stones are laid in regular courses, not less than 15 cm in height, and up to a maximum of 30 cm. All the courses shall be of the same height unless otherwise specified. The length of the stone shall not be less than twice the height and the breadth at base shall not be greater than three fourth the thickness of the wall nor less than 15 cm. The faces that are to remain exposed in the final construction and the adjoining faces shall be fine chisel dressed to a depth of 6 mm so that when checked with a straight edge the variation shall not be more than 1 mm. The courses shall be laid headers and stretchers alternately unless otherwise specified, and the headers shall be arranged to come as nearly as possible in the middle of stretcher above and below. Bond stones shall be provided in every course, 1.5 to 1.8 m apart. The face joints in the work shall not be more than 5 mm thick.

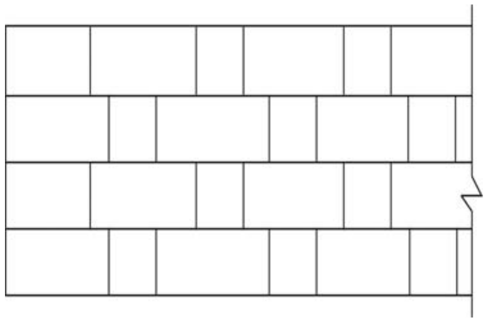


Figure 2.16 : Plain Ashlar Masonry

Punched Ashlar

This is similar to plain ashlar except that all exposed faces shall have a fine chisel draft 2.5 cm wide all round the edges, and shall be rough tooled between the drafts, such that the dressed surface does not show a variation of more than 3 mm when checked with a straight edge. This is also known as rough tooled ashlar shown in Figure 2.17.

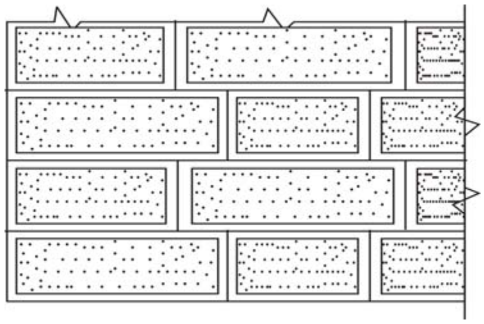


Figure 2.17 : Punched Ashlar Masonry

Ashalr Rockfaced

This type is like punched ashlar with chisel drafting all round the edges of the exposed face, but the portion within the draft is left rough as it comes from the quarry except for light hammer dressing to restrict the bushing (projection from the plane of drafts) to 75 mm (Figure 2.18).

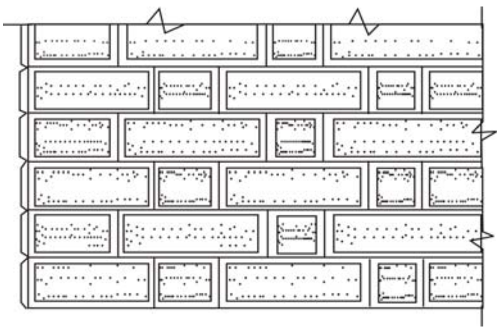


Figure 2.18 : Ashlar Rockfaced Masonry

Ashlar Chamfered

This is similar to plain ashlar except that the edges of the exposed faces are chamfered to an angle of 45^o to a depth of 25 mm as shown in Figure 2.19.

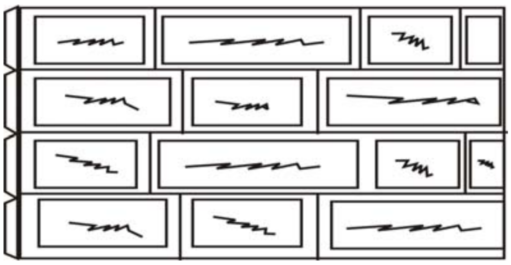


Figure 2.19 : Ashlar Chamfered Masonry

Ashlar Facing

Here the main wall may be of rubble masonry, brickwork or concrete onto which a facing of ashlar is provided. In this construction, the appearance is improved by ashlar face but all the same cost is reduced. The back face of the stone may be left rough for better adhesion. Bond stones should be provided over the full thickness, including the backing.

2.5.2 Stone Masonry

Construction Practices

Bureau of Indian Standards has laid detailed rules regarding construction practices. However, in general, following principles in this regard are in order :

Mortar for Joints

Same types of mortars are used in stone masonry as in the case of brickwork. Generally, good quality stonework is built in cement mortar 1 : 3.

Curing

All faces of the masonry work shall be kept moist for a minimum period of seven days.

Scaffolding

While single scaffolding can be allowed for rubble masonry, it would be preferable to have double scaffolding for coursed rubble masonry of first sort.

In the case of ashlar work, only double scaffolding should be permitted.

SAQ 3

(a) What are the common types of building stone and in what situations are they used?

(b) What is a bond stone and what is its purpose? At what intervals would you provide bond stones in random rubble, coursed rubble and plain ahslar masonry?

2.6 BLOCK MASONRY

Various types of blocks can also be used to construct masonry. As these blocks can be made under controlled conditions it is possible to achieve the desired quality. As they can be made to sizes larger than bricks and at the same time true to size and shape, the construction is faster and the quantity of mortar required for the masonry work is less. The faces of blocks being fairly smooth, the walls can be left unplastered, and even if they are plastered the quantity of mortar required would be less than in brick masonry and very much less than in stone work.

A variety of blocks are available for use, such as concrete blocks, lime based blocks, soil based blocks etc.

Concrete Blocks

Blocks can be solid or hollow. They can be hand made or machine made. The materials required for their manufacture are cement, aggregate and water. Fly ash or other admixtures are also sometimes used. The concrete mix used for the manufacture of blocks is normally (1 cement to 5 or 6 of combined aggregates) by volume. The fineness modulus of the combined aggregate shall be between 3.6 and 4. The blocks can be compacted in the moulds manually or preferably manufactured in block making machines. The blocks shall be cured for 14 days. Steam curing can be adopted to save time.

The nominal dimensions of concrete blocks are as given below :

Length : 400, 500 or 600 mm

Width : 50, 75, 100, 150, 200, 250 or 300 mm

Height : 100 or 200 mm

Hollow concrete blocks are manufactured in three grades, as described below :

Grade A

Load bearing units with a minimum density of 15 kN/m^3. The average compressive strength shall be 3.5, 4.5, 5.5 or 7 N/mm^2. The thickness of the face shell and web shall not be less than 25 mm.

Grade B

Load bearing unit with a block density between 10 to 15 kN/m^3. The average compressive strength shall be 2, 3 or 5 N/mm^2.

Grade C

Non-load bearing units with block density between 10 to 15 kN/m^3. The average compressive strength shall not be less than 1.5 N/mm^2.

Solid concrete blocks are made for load bearing units with a block density of not less than 18 kN/m^3. The average compressive strength shall be between 4.0 to 5.0 N/mm^2.

The water absorption of the concrete blocks shall not exceed 10% by weight.

Precast Concrete Masonry Blocks

These are precast solid concrete blocks embedded with stone spalls, i.e. broken stone pieces (20 to 30% by volume). The concrete is usually made of 1 part of cement and 9 parts of combined fine and coarse aggregate. The mix is placed in the mould in layers along with stone spalls and compacted.

The blocks are cured for 14 days. The density and strength characteristics are similar to that of solid concrete blocks.

Lime Based Blocks

These are made from a combination of materials consisting of lime, cement, fly ash, burnt clay pozzolana etc.

The normal nominal sizes of blocks are :

Length : 400 mm

Width : 100, 200 or 300 mm

Height : 100 or 200 mm

The density is of the order of 10 kN/m^3 and compressive strength 3.5 N/mm^2.

Lime Flyash Bricks

They are made from fly ash (80-90%), sand (2-12%) and lime (1-10%) with small quantity of chemical accelerator. They have a density of 15 kN/m^3 and a compressive strength of 7.5 to 10 N/mm^2.

Sand Lime Bricks

It is composed of sand (91-93%) and lime (7-9%). The components are mixed with water and compressed in moulds under pressure and then autoclaved. The density is 8 kN/m^3 and compressive strength 10 N/mm^2.

Flyash Lime Gypsum Bricks

This is made from a mixture of flyash, lime, gypsum and sand. After mixing with water, the mixture is compacted in moulds and cured. The density is 14 kN/m^3 and compressive strength 8 to 10 N/mm^2.

Autoclaved Aerated Concrete Blocks

These are made from the sand or selected quality of flyash or mixtures of both and a binder of lime and cement. The cellular character of the blocks, which gives good thermal properties and a high strength to density ratio, is formed as a result of aeration caused by adding traces of aluminium powder. These blocks have a density of 6.5 kN/m^3 and compressive strength of 3.5 to 4.0 N/mm^2. They have high thermal and sound insulation properties and are fire resistant also.

Soil Based Blocks

Most of the soils can be satisfactorily stabilised by the addition of lime or cement. It is however necessary to analyse the properties of the soil through a laboratory testing to determine the optimum quantity of stabilisers to be added to impart the desired properties to the block. Soil containing 0-10% gravel, 40-75% sand, 15-25% silt, and 8-25% clay is suitable for making blocks. It should not contain more than 0.5% of organic matter and the pH value should be less than 7. Soil based blocks are cheap and can be used with advantage in the construction of low cost houses.

These blocks are manufactured from the mixture of suitable soil and a stabilizer (cement, lime or gypsum or a combination) thoroughly mixed, preferably in a mechanical mixer at suitable moisture content and then pressed into moulds. The blocks are cured for 14 days by gently sprinkling water. Cement (5% by weight) is generally recommended for non-cohesive soils with low clay content while a combination of cement and lime (2.5% by weight of each) can be used if the clay content is higher. The nominal sizes of the blocks are 20 × 10 × 10 cm, 20 × 10 × 5 cm and 30 × 20 × 10 cm. The density of the block is about 20 kN/m^3 and the compressive strength of the order of 2 to 3 N/mm^2. Water absorption of the block should be less than 20%.

2.6.1 Blocks Masonry

Construction Practices

The mortar can be cement-sand, lime-sand or combination mortars. The strength of the mortar should be weaker than the strength of the blocks to avoid formation of cracks. Cement sand mortars of 1 : 4 : to 1 : 6 and corresponding lime or combination mortars could be used.

The blocks may be slightly wetted/moistened before construction to prevent absorption of water from the mortar and also to ensure proper adhesion with the mortar. The masonry should be constructed to a suitable bond so that the vertical joints in successive layers are staggered. The work shall be cured appropriately for due period of time. Scaffolding shall be single or double depending on the importance of the work.

2.7 WORKMANSHIP AND QUALITY ASSURANCE IN MASONRY CONSTRUCTION

Brick masonry is usually classified as first, second and third class depending on the strength, characteristic and uniformity of shape of bricks and also the workmanship as well as the mortar used.

Stone masonry is classified into various types depending on the preparation of stone pieces and labour involved. Random rubble masonry requires least amount of preparation of stone. Ashlar masonry involves maximum preparation of stone. Stones shall be laid on their planes and dressed properly.

In stone masonry, bond stones or through stones which run through thickness of the wall are very important. The stones should be laid breaking joints and should overlap each other making it a homogeneous mass.

Corner in a stone masonry like window door joints walls etc. are very important. Special type of stones called quions should be used.

In case of veneer work, clamps and cramps should be used at proper intervals and shall be of the size and material specified.

The following points shall be checked while supervising masonry construction :

(a) Brick shall be checked for strength, efflorescence, dimensional accuracy, water absorption and proper burning. Stones should be checked for uniformity of colour, strength, texture, compressive strength and water absorption.

(b) Grading and silt content of sand for mortar.

(c) In brick masonry, thickness of joint shall not exceed 1 cm.

(d) The joints shall be filled up with mortar.

(e) Joints shall be staggered.

(f) In brick masonry, face joints shall be raked to a depth of 15mm when the mortar is still green.

(g) Masonry should be plumb or in specified batter.

(h) Bricks and stones should be fully soaked in water and laid skin dry.

(i) Brick courses and ashlar masonry should be laid level.

(j) Mortar should be properly mixed on a hard platform.

(k) Strength of mortar can be checked by scratching with any sharp instrument.

(l) Joints between main and cross walls should be properly bonded.

(m) Curing should be proper and at least for seven days.

(n) General quality of works with respect to lines, levels, thickness and trueness of the joints.

(o) In brick masonry, top courses in plinth, in window sill, below RCC slab and parapet shall be provided in brick on edge.

(p) Holes of scaffolding should be properly filled up.

(q) Specified reinforcement in half brick masonry and in corners etc. shall be provided.

(r) Required number of bond stones to be provided.

(s) Quality of dressing.

(t) In stone masonry, thickness of joints should not be excessive.

(u) Cramps and dowels to be checked for materials size and number.

(v) All pipe fittings and specials, spouts, hold fasts and other fixtures which are required to be built into the walls shall be embedded, as specified, in their correct positions as the masonry work proceeds.

(w) To facilitate taking service lines later without excessive cutting of completed work sleeves shall be provided where specified, while raising the masonry work.

(x) Outlets shall be provided wherever water is likely to accumulate.

2.8 SYSTEM OF BUILDING STRUCTURES

There are primarily the following three systems of a building structure :

Load Bearing Structure

In this system, the load bearing walls are constructed on a continuous foundation and they are designed to support the entire load including their own load. Hence in this type of structure, the beams, trusses, or other heavy parts and fittings are always made to rest on load-bearing walls.

Framed Structure

In this system, a number of piers or columns are erected on their own independent foundations and are braced together by beams and floors. In this way, the whole structure is erected including the roof, and the gaps between the piers or columns are filled with walls, which are called 'panel', 'curtain', and 'screen or filler walls'. The function of walls is simply to support their own weight and to serve as a screen for privacy and afford protection against weather effects. The frame carries the entire load on the structure both live and dead.

Composite Structure

In this system, which is combination of a load bearing structure and framed structure, the outer side walls consist of bearing walls whereas the frame of columns and beams rests with one end on bearing walls and the other end on inner columns with thin partitions between bearing walls.

SAQ 4

What are the relative advantages and disadvantages of brick, stone and block masonry constructions?

2.9 SUMMARY

In this unit, we have studied the functions served by various types of wall. The characteristics of bricks, tests to be carried out on them to assess their suitability, different types of mortar used in masonry, importance of bonds and constructional details of brick masonry have been explained. Similarly, various aspects of stone masonry have also been given. We have also seen that masonry can be constructed with blocks, manufactured from a variety of materials. Lastly the workmanship and quality assurance in masonry construction have been discussed.

In the next unit, you will be introduced to the different treatments normally employed in the building for curbing termites and dampness.

2.10 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section 'Further Reading' given at the end to get the answers of the SAQs.

UNIT 3 ANTI-TERMITE, DAMP PROOFING AND WATER PROOFING

Structure

3.1 INTRODUCTION

Anti-termite treatment and damp proofing are the essential requirements to ensure safety of buildings against termite and dampness. All possible measures and techniques to achieve these two basic requirements will be discussed in this unit. We shall deal with types of termite, anti-termite treatment, damp proofing, sources or causes of dampness and its effects, methods of damp proofing and damp proof treatments of buildings.

Objectives

After studying this unit, you should be able to

- conceptualise problem of termites and their effects,
- explain different types of anti-termite treatment commonly used to prevent damages due to termites,
- discuss damp proofing and water proofing, their causes and effects in buildings, and
- describe various materials and methods used for damp proofing treatments in the buildings.

3.2 ANTI-TERMITE

Insects have been in existence for millions of years and they are capable of survival under most adverse conditions and environments. Termites, also types of insects, cause maximum damage to the buildings. Termites, popularly known as white ants, cause considerable damage to wood work, furnishings etc. of buildings. In some countries, the loss caused due to termites is estimated to be as high as 10% of the capital outlay of the buildings. *Anti-termite treatment* is, therefore, necessary so that damages due to termites are either reduced or stopped all together.

3.3 TYPES OF TERMITE

Termites are divided mainly into following two types. These are

(a) dry wood termites, and

(b) subterranean termites.

Dry Wood Termite

Dry wood termites live in wood and do not maintain contact with the ground. They normally build nests within the dry timber members like door window frames, wooden furniture etc. and destroy them gradually. They are, however, not as common as subterranean termites and they cause lesser damage to the buildings.

Subterranean Termites

Subterranean termites on the other hand live in soil and require moisture for their existence. They are mainly responsible for causing damage to the buildings and its contents. They build underground nests or colonies and form mud-wall tunnels or runways (tubes), which serve as safe shelter for their movements. Sometimes they build nests near ground in stumps of dead trees or create colonies in the form of dome shaped mounds on the ground. It is through these mud wall tubes that they maintain direct contact with the soil for meeting their moisture requirements. These mud walls also create conditions of darkness, which is essentially needed for their survival. The termites enter the building through foundations or from ground adjacent to buildings and advance upward through floors destroying everything that comes within their reach. They may also enter the building through cracks in masonry and joints or cracks in floors in contact with ground. Termites eat celluloses materials like wood, grass, etc. and also attack materials like leather, plastics, rubber, furniture, furnishings; clothing, stationery etc.

3.4 ESSENTIALS OF TERMITE-PROOFING

A careful examination of untreated building can show that damage by termites and evidence of their activity is not difficult to find. Often such damage or termite activity can be found on the upper floors as well. Even if termite damage on the lower floors is not clearly visible, this should not lead to the conclusion that they have not established a colony on the upper floors.

The termite-proofing treatment should invariably be given to all types of buildings during the construction stage. It is because of the fact that during the post-construction period, it is extremely difficult and costly to control the termite growth. Care should be taken to ensure that no bridge is formed between any part of building and untreated soil. In order to reclaim land by utilizing debris or filling material, great care should be exercised to ensure that debris is termite-free. As far as possible metal strain or suitable joint fillers may be used to make the floor joints free from termite attack. To check termite movements from ground, the foundations should be either made of concrete or any other solid material. Also, care should be taken to ensure that building site is free from dead wood, old tree stumps, etc. The superstructure should be treated with suitable preservatives to make it termite-proof. All the wooden members like door frames, stair-cases, etc. should be set on flooring. They should not be through flooring to prevent ground soil contact.

3.5 TYPES OF ANTI-TERMITE TREATMENT

The anti-termite treatment in buildings may be divided into two categories :
Pre-construction treatment and Post-construction treatment

3.5.1 Pre-construction Treatment

Pre-construction treatment is the kind of anti-termite treatment carried out right from the stage of initiating the construction activities for the building. The various stages involved in this treatment are described below.

Site Preparation

This consists in removing stumps, roots, logs, waste-wood etc. from the site where the building is to be constructed. In case the termites mound are discovered within the plinth area of the building they should be destroyed by use of insecticide solution. For this treatment, holes should be made into the mound at several places by use of crow-bar and the insecticides taken in the form of water suspension or emulsion should be poured into the holes. The quantity of insecticides solution to be used depends on the size of mound. For a mound having volume of about 1 cu.m., 4 litres of an emulsion in water of one of the following chemicals may be used :

DDT 5%,

BHC 0.5%,

Aldrin 0.25%

Heptachlor 0.2%

Chlordane 0.5%

(Here, chemical concentration is expressed by weight.)

Soil Treatment

The most reliable method to protect building against termites is to apply a chemical treatment to the soil at the time of construction of the building. This treatment consists in poisoning the soil underneath the building and around the foundations of the buildings with insecticide solution. This should be done in such a way that a complete chemical barrier is created between the ground from where the termites come and damage wood work in the building. An insecticide solution consists of anyone of the following chemicals in water emulsion :

(a) Aldrin 0.5%

(b) Heptachlor 0.5%

(c) Chlordane 1% (whereas chemical concentration is expressed by weight).

In order that the soil treatment may be fully effective, the chemical water emulsion should be applied in required quantity on entire area of ground covered by the building. To ensure uniform distribution of the chemical emulsion, a watering can or hand operated compressed air sprayer can be used. The soil treatment should be applied in the following stages :

Wall Trenches, Column Pits and Basements

The bottom surface and the sides of the foundation trenches, column pits and basements should be treated by applying chemical water emulsion at the rate of 5 litres per square meter of the surface area. After the foundation for the walls, columns, piers and retaining walls of the basement come up, treat the back fill earth in immediate, contact with each side of the foundation with the chemical emulsion at the rate of 7.5 liters per square meter of the vertical surface of the foundation masonry. This treatment is essentially to be given to masonry foundation with a view to ensure that the termites do not gain entry into the building through the voids in the joints in the masonry.

In case of RCC columns or RCC basement walls, there is no possibility of voids, which can permit entry of termites, and hence it is not necessary to start anti-termite treatment right from the bottom of excavation. In such cases, the treatment should start at depth of 500 mm below ground level. The back fill around RCC columns, beams and entire basement walls from a depth of 500 mm up to ground level should be treated with chemical emulsion at the rate of 7.5 liters per square meter of vertical surface.

Top Surface of Plinth Filling

Prior to laying the sand bed or sub grade for the ground floor of the building, top surface of the consolidated earth filling within the plinth walls should be levelled and treated with chemical emulsion to 5 liters per square meter of the surface.

Junctions of the Wall and Floor

The junctions of walls and the floors require special attention to ensure effective soil treatment. It is important to establish vertical continuity of the poisoned soil barrier on inner wall surface up to top of consolidated earth filling in plinth. This is achieved by making 30 mm wide and 30 mm deep channels at the junction of walls and columns with the earth filling in plinth. Holes are thereafter made in the channel at 150 mm apart up to ground level and then chemical emulsion is poured in the channel at the rate of 7.5 liters per square meter of the vertical wall or column surface. After the treatment the earth should be immediately tamped back into the holes and channel.

Soil along External Periphery of Building

Despite the treatments given above, termites are liable to gain excess in the building from ground surface around the external periphery of the building. In order to check this, 300 mm deep holes at 150 mm centre are dug all along the external perimeter of the building (parallel to the external wall) and filled with chemical emulsion at the rate of

2.25 liters per linear meter. After the treatment, the earth should be tamped back in the holes.

Expansion Joints

The expansion joints are given additional treatment by applying chemical emulsion at the rate of 2 liters per linear meter after the sub grade for floor on either side of expansion joints has been laid. This treatment is in addition to the treatment, which is necessarily provided to the structure up to top of consolidated earth fill within plinth.

Structural Barriers

Impenetrable physical structural barriers may be provided continuously at plinth level to prevent entry to termites through walls. These barriers may be in the form of concrete layer or metal layer. Cement concrete layers should be 5 to 7.5 cm thick and should preferably be kept at projecting about 5 to 7.5 cm internally and externally. Metal barrier may consist of non-corrodible sheets of copper or galvanized iron of 0.8 mm thick. These sheets are likely to be damaged; in that case, they become ineffective against termites movement.

3.5.2 Post-construction Treatment

Though it is always advisable to go for pre-construction treatment but in case when pre-construction treatment has not been properly carried out and termites affect building then post-construction treatment becomes essential. This treatment is applied to existing buildings, which have already been attacked by termites. It is observed that even after their entry in the building, the termites maintain regular contact with their nest in the ground. This important symptom is well utilized in eradicating termites from the buildings. Regular inspection and suitable control measures are necessary to prevent damage to buildings from termites.

At times when the termite's attack is of minor nature it may only be necessary to break off the shelter tubes to check the damage from termites. In situations where the attack is of mild nature the effected materials may also be removed along with shelter tubes. In case of severe attack it is necessary to poison the soil around and beneath the building besides resorting to the above steps. The type of treatment to be given to eradicate termites from the existing building largely depend upon the extent of attack and the magnitude of cellulosic and other materials available in the building. The various operations involved in eradicating termites from an existing building can be summarized as follows :

Inspection

Inspection is essentially carried out to estimate the magnitude of spread of the termite's infestation in the building and also to detect the root of the entry of termites and the zones in the building, which are attacked. The portion of the building in contact with or adjacent to the earth should be inspected first. This includes basements, ground floor, steps leading from ground, walls, columns, areas having damp or humid conditions like bathrooms, lavatories, leaking pipes or drains etc. and the places where wood work is embedded in the floor or wall. The ceilings, wooden paneling, battens for wiring conduits, switch boards are other locations which serve as hide-out for the termites and need careful inspection.

In case of multi-storied buildings, lift wells, casings covering electrical wiring, telephone cable, water supply and soil pipes which serve as convenient and well protected zones for termite's infestation should also be inspected carefully.

Wherever the mud walled shelter tubes or the termites runways are detected, they should be removed. Wherever possible, oil or kerosene based chemical emulsion should be injected over the attacked areas of wood work and masonry. At times, structural additions may become necessary to ensure elimination of all direct contacts between the soil and the affected portion of the structures.

Soil Treatment for Foundations

This treatment consists in treating the soil under the building and around the chemical emulsion, which can kill or repel termites. In this treatment, about 500 mm deep trenches are made along the external periphery of the wall of the building and 15 mm diameter holes at 150 mm centers are then made in the trenches close to the wall face. The holes should preferably extend up to the top of footing of foundations or to a depth of at least 500 mm whichever is lesser. These holes are then filled with chemical emulsion in water and the back fill earth is also sprayed with the chemical emulsion as it is returned to the trench thereby creating a barrier of poisoned soil along the external periphery of the building. The total quantity of the chemical to be used in this treatment should be at the rate of 7.5 litres per square meter of the vertical surface of the masonry in foundation.

In case of RCC frame structure, the chemical treatment shall be applied to the soil in contact with column side and plinth beams along external periphery of the building for a depth of 500 mm below ground level. In case the building has masonry or concrete apron, about 12 m diameter holes at 300 mm centre to centre should be drilled close to the plinth wall along the apron. The holes should be deep enough to reach the soil below. Chemical emulsion should thereafter be pumped into these holes at the rate of 2.5 litres per linear metre of the length of the apron.

Soil Treatment under Floor

Cracks in floors are the weak spots, which permit entry of termites from soil below the floor. The cracks usually occur at the junction of the floor and walls, expansion joints in floor and at construction joints in a concrete floor. Cracks in floors may also develop due to use of unsound materials or on account of defective workmanship. In such cases, eradication of termites is achieved by poisoning the soil underneath the floors wherever such cracks are noticed. Drilling 12 mm diameter holes at 300 mm centre to centre all along the cracks in the floors in different areas and then injecting chemical emulsion into the holes till the soil below gets fully saturated generally carry out this operation. The maximum quantity of chemical emulsion may, however, not exceed one liter per hole. The holes in floors are sealed after treatment.

Treatment of Voids in Masonry

It has been seen that termites enter into masonry foundations from soil adjacent, beneath the building and work their way up through voids in the masonry joints and gain entry into the interior of the buildings. To prevent the entry of the termites through voids in masonry, 12 mm diameter holes at 300 mm centre to centre are drilled at downward angle of about 45^{o} from both sides of walls at plinth level and then chemical emulsion is pumped into the holes until masonry gets fully saturated with the chemical emulsion. The holes are then sealed. This treatment is carried out for all walls (both internal as well as external) having foundation in soil. Treatment of drilling hole and pumping chemical emulsion should also be carried out at critical locations like wall corners and at places where door and window frames are embedded in masonry in ground floor.

Treatment of Wood Work

Wood work which is badly damaged by termites should be replaced by new timber which is adequately brushed or dipped in oil or kerosene based chemical emulsion. The infected wood work for door and window frames, etc. should be given protective treatment by drilling 6 mm diameter holes at 150 mm centre to centre at a downward angle of 45^o to cover the entire framework and thereafter pumping oil based chemical emulsion into the holes. The wood work which is not attacked by termites should be sprayed over with chemical emulsion to prevent possible attack.

SAQ 1

(a) Define and briefly describe about termites and their types.

(b) Describe about pre-construction anti-termite treatment.

(c) Explain how post construction anti-termite treatment is carried out in buildings?

3.6 DAMP PROOFING AND WATER PROOFING

A building should remain dry or free from moisture traveling through walls, roofs or floors. If this condition is not satisfied, the building may become damp. *Dampness* is the presence of hygroscopic or gravitational moisture. Dampness in building gives rise to unhygienic conditions apart from reduction in strength of structural components of the building. Prevention of dampness is, therefore, one of the important items of building design. Every building should be damp proof. The provisions made to prevent the entry of damp into a building are known as the *damp proof courses* (DPC). These are provided at various levels of entry of damp into a building. Thus provision of damp-proofing courses prevents the entry of moisture from walls, floors and basement of a building. The treatment given to the roofs of a building for the same purpose is known as the waterproofing.

3.6.1 Causes of Dampness

Dampness in buildings is generally due to faulty design and construction, poor workmanship or due to use of poor quality material in construction. These causes give rise to an easy access to moisture to the building from different points, such as rising of moisture from ground, rain penetration through walls, roofs and floors, etc. The moisture, entering the buildings from foundation and roofs, travels in different directions further under the effects of capillary action and gravity, respectively. The entry of water and its movements, in different parts of the building, are due to one or more of the causes listed above. The various sources that create dampness in buildings can be categorized as follows :

Moisture Rising from the Ground

The sub-soil or ground on which the building is constructed may be made of soils, which easily give an access to water to create dampness in buildings, through the foundations. Generally, the foundation dampness is caused when the building structures are constructed on low-lying waterlogged areas, where a sub-soil of clay or peat is commonly found, through which dampness will easily rise under capillary action unless properly treated. This dampness further finds its way to the floors, walls, etc. through the plinth.

Rain Beating against External Wall

Heavy showers of rain may beat against the external faces of walls and if the walls are not properly treated, moisture will enter the wall, causing dampness in the interior. If balconies and chajja projections do not have proper outward slope, water will accumulate on these and could ultimately enter the walls through their junction. This moisture travel would completely deface interior decoration of the wall.

Rain Penetration from Tops of Walls

All parapet walls and compound walls of the building which have not been protected from rain penetration by using damp proof course or by such measures on their exposed tops are subjected to dampness. This dampness in buildings is of serious nature and may result in unhealthy living conditions or even in structurally unsafe conditions.

Condensation

Whenever the warm air in the atmosphere is cooled, it gives rise to the process of condensation. On account of the condensation, the moisture is deposited on the whole area of walls, floors and ceilings. However, this source of dampness is prevalent only in certain places in India where very cold climates exist.

Miscellaneous Sources or Causes

The various other sources or causes which may be responsible for dampness in buildings are mentioned below :

Poor Drainage of the Site

The structure, if located on low-lying site, causes waterlogged conditions where impervious soil is present underneath the foundations. So, such structures, which are not well drained, cause dampness in buildings through the foundations.

Imperfect Orientation

Whenever the orientation of the buildings is not proper or geographical conditions are such that the walls of building get less of direct sunrays and more of heavy showers of rains, then such walls become prone to dampness.

Constructional Dampness

If more water has been introduced during construction or due to poor workmanship, the walls are observed to remain in damp condition for sufficient time.

Dampness Due to Defective Construction

The dampness in building is also caused due to poor workmanship or methods of construction, viz. inadequate roof slopes, defective rain water pipe connections, defective joints in the roofs, improper connections of walls, etc.

3.6.2 Effects of Dampness

The various effects caused due to dampness in buildings are mentioned below. All these effects mainly result in poor functional performance, ugly appearance and structural weakness of the buildings.

(a) Dampness gives rise to breeding of mosquitoes and creates unhealthy living conditions for occupants.

(b) Travel of moisture through walls and ceiling may cause bleaching and flaking of the paint, which results in formation of colored patches on the wall surfaces and ceilings.

(c) Presence of damp conditions causes efflorescence on building surfaces, which ultimately may result in the disintegration of bricks, stones, tiles etc. and hence in the reduction of strength.

(d) It may result in softening and crumbling of plaster. The wall decoration (i.e. painting etc.) is damaged, which is very difficult and costly to repair.

(e) The flooring gets loosened because of reduction in the adhesion when moisture enters through the floor.

(f) Floor coverings are damaged; on damp floors one cannot use floor coverings.

(g) Timber fittings, such as doors, windows, almirahs, wardrobes, when come in contact with damp walls, damp floors, get deteriorated because of warping, buckling, dry rotting of timber.

(h) Dampness promotes and accelerates growth of termites.

(i) Electrical fittings get deteriorated, giving rise to leakage of electricity and consequent danger of short-circuiting.

(j) Moisture causes rusting and corrosion of metal fittings attached to walls, floors and ceilings.

(k) Dampness, when accompanied by the warmth and darkness, breeds the germs of tuberculosis, neuralgia, acute and chronic rheumatism etc., which, sometimes, result in fatal diseases. Occupants may even be asthmatics.

3.6.3 Precautions to Prevent Dampness

The following precautions should be taken to prevent the dampness in buildings, before applying the various techniques and methods described later :

(a) The site should be located on a high ground and well drained soil to safeguard against foundation dampness. It should be ensured that the water level is at least 3 meters below the surface of ground or lowest point even in the wet season. For better drainage, the ground surface surrounding the building should also slope away from the house or structure.

(b) All the exposed walls should be of sufficient thickness to safeguard against rain penetration. If walls are of bricks, they should be made of at least 30 cm thickness.

(c) Bricks of superior quality, which are free from defects such as cracks, flaws, lump of lime stones, etc. should be used. They should not absorb water more than 1/8 of their own weight when soaked in water for 24 hours.

(d) Good quality cement mortar (1 cement : 3 sand) should be used to produce a definite pattern and perfect bond in building units throughout the construction work. This is essential to prevent the formation of cavities and occurrence of differential settlement, due to inadequate bonding of units.

(e) Cornices and string courses should be provided. Window sills, coping of plinth and string courses should be sloped on top and throated on the underside to throw the rain water away from the walls.

(f) All the exposed surfaces like tops of walls, compound walls, etc. should be covered with waterproofing cement plaster (i.e. 1 cement : 3 sand + water proofing compound).

(g) Hollow walls (i.e. cavity walls) are more reliable than solid walls in preventing dampness and hence the cavity wall construction should be adopted wherever possible.

3.6.4 Materials Used for Damp Proofing Course

An ideal damp proofing material should have the following characteristics :

(a) The material should be perfectly impervious and it should not permit any moisture penetration to travel through it.

(b) The material should be durable and should have the same life as that of the building.

(c) The material should be strong, capable of resisting superimposed loads/pressure on it.

(d) Material should be flexible, so that it can accommodate the structural movements without any fracture.

(e) The material should not be costly.

(f) The material should be such that leak-proof jointing is possible.

(g) The material should remain steady in its position when once applied. It should not allow any movement in itself.

Following materials are commonly used for damp-proofing course :

Hot Bitumen

It is highly flexible material, which can be applied with a minimum thickness of 3 mm. It is placed on the bedding of concrete or mortar in hot condition.

Mastic Asphalt

Mastic asphalt is semi-rigid material, which is quite durable and completely impervious. It is obtained by heating asphalt with sand and mineral fillers. However, experienced persons should lay it very carefully.

Bituminous or Asphaltic Felts

This is a flexible material, which is available in rolls of various thicknesses. It is laid on a leveled flat layer of cement mortar. An overlap of 10 cm is provided at joints and full width overlap is provided at angles, junctions and crossings. The laps should be sealed with bitumen. Bituminous felts cannot withstand heavy loads, though they can accommodate slight movements.

Plastic Sheets

Plastic sheets made of black polythene are also being used as a type of DPC material. These sheets are 0.5 to 1 mm thick in the usual walling width and roll lengths of 30 m.

Metal Sheets

Sheets of lead, copper, aluminium can be used as DPC. These sheets are of flexible type. *Lead sheets* are quite flexible. They are laid similar to the bituminous felt. Lead sheets have the advantages of being completely impervious to moisture, resistant to ordinary atmospheric corrosion, capability of taking complex shapes without fracture and resistant to sliding action. It does not squeeze out under ordinary pressure. However, it may be corroded when in contact with lime or cement. A coating of bitumen should, therefore, protect it. *Copper sheets* of minimum 3 mm thicknesses, are embedded in lime or cement mortar. It has high durability, high resistance to dampness, high resistance to sliding and reasonable resistance to ordinary pressure. *Aluminium sheets*, if used, should be protected with a layer of bitumen. It is not as good as lead or copper sheets.

Combination of Sheets and Bituminous Felts

Lead foil sandwiched between asphaltic or bituminous felts can be effectively used as DPC. The combination, known as lead core, possesses characteristics of easy laying, durability, efficiency, economy and resistance to cracking.

Bricks

Special bricks, having water absorption not less than 4.5 % of their weight may be used as DPC in locations where damp is not excessive. These bricks are laid in two to four courses in cement mortar. The joints of bricks are kept open.

Stones

Dense and sound stones, such as granite, trap, slates, etc. are laid in cement mortar (1 : 3) in two courses or layers to form effective DPC. The stones should extend to the full width of the wall.

Mortar

Cement mortar (1 : 3) is used as bedding layer for housing other DPC materials. A small quantity of lime may be added to increase workability of the mortar. This mortar may also be used for plasterwork on external walls.

Cement Concrete

Cement concrete of 1 : 2 : 4 mix or 1 : 1.5 : 3 mix is generally provided at plinth level to work as DPC. The thickness may vary from 4 cm to 15 cm. Such a layer can effectively check the water rise due to capillary action. Where dampness is more, two coats of hot bitumen paint may be applied on it.

SAQ 2

(a) What is dampness in building? Discuss its possible causes and effects on the performance of a building structure.

(b) What do you understand by the term “Damp-proofing”? Explain.

(c) Mention the precautions that should be taken for preventing dampness in building.

3.7 METHODS OF DAMP PROOFING

Following methods are adopted to make a building damp proof :

(a) Use of damp proofing course (DPC) or membrane damp proofing,

(b) Integral damp proofing,

(c) Surface treatment,

(d) Cavity wall or hollow wall construction,

(e) Guniting or shot concrete, or shotcrete, and

(f) Pressure grouting or cementation.

Use of Damp-Proofing Courses (or DPC)

These are the layers or membranes of water repellent materials such as bituminous felts, mastic asphalt, plastic sheets, cement concrete, mortar, metal sheet, slates, stones, etc., which are interposed in the building structures at all locations wherever water entry is anticipated or suspected. These damp proof courses of suitable materials should be provided at appropriate locations for their effective use. Basically, DPC is provided to prevent the water rising from the sub-soil or ground and getting into the different parts of the building. The best location or position for DPC in case of buildings without basements, lies at the plinth level or in case of structures without plinth it should be laid at least 15 cm above the ground level (Figure 3.1). These damp-proof courses may be provided horizontally or vertically in floors, walls etc.

Figure 3.1 : DPC Above Ground Level

Integral Damp Proofing

This consists of adding certain water proofing compounds of materials to the concrete mix, so that it becomes impermeable. These water proofing compounds may be in various forms like compounds made from chalk, talc etc., which may fill the voids of concrete. Compounds like alkaline silicates, aluminium sulphate, calcium chlorides etc., react chemically with concrete to produce water proof concrete. Compounds, like soap, petroleum, oils, fatty acid compounds such as stearates of calcium, sodium, ammonia etc. work on water repulsion principle. When these are mixed with concrete, the concrete becomes water repellent. Some commercially available compounds used for this purpose are Publo, Permo and Silka.

Surface Treatment

The surface treatment consists of application of layer of water repellent substances or compounds on these surfaces through which moisture enter. The use of water repellent metallic soaps such as calcium and aluminium oletes and stearates are much effective against rain water penetration. Pointing and plastering of the exposed surfaces must be done carefully using water proofing agents like sodium or potassium silicates, aluminium or zinc sulphates, barium hydroxide and magnesium sulphates etc. It should be noted that surface treatment is effective only when the moisture is superficial and is not under pressure. Sometimes, exposed stone or brick wall face may be sprayed with water repellent solutions.

Cavity Wall Construction

This is an effective method of damp prevention, in which an outer skin wall, leaving a cavity between the two, shields the main wall of a building. For details about cavity wall construction learner may refer other standard text.

Guniting or Shot Concrete or Shotcrete

This consists of depositing under pressure, an impervious layer of rich cement mortar over the exposed surfaces for water proofing or over pipes, cisterns etc. for resisting the water pressure. Cement mortar consists of 1: 3 cement sand mix, which is shot on the cleaned surface with the help of a cement gun, under a pressure of 2 to 3 kg/sq. cm. The nozzle of the machine is kept at a distance about 75 to 90 cm from the surface to be gunited. The mortar mix of desired consistency and thickness can be deposited to get an impervious layer. The layer should be properly cured at least for 10 days.

Pressure Grouting or Cementation

This consists of forcing cement grout, under pressure, into cracks, voids, fissures etc. present in the structural components of the building, or in the ground. Thus the structural components and the foundations, which are liable to moisture penetration, are consolidated and are thus made water penetration resistant. This method is quite effective in checking the seepage of raised ground water through foundations and sub-structure of a building.

3.8 DAMP PROOFING TREATMENT IN BUILDINGS

Damp-proofing treatment in buildings is carried out for its different components like treatment to foundations, floors, walls, roofs and parapet walls etc. Following section presets damp proof treatment given to these components.

Treatment to Foundation

Before dealing with the problem of damp proofing treatment to be given to foundations, it is essential to have an idea about the ground water level. When it rains, the rain water seeps through the ground until it is stopped by an impervious layer in the sub-soil strata. The strata of ground above the water table attract water by capillary action. The height of capillary rise depends on the size of voids in the soil. It is noticed that in case of fine grained soils like clay, silty clay etc., ground water can rise more than 6 m by capillary action. In case of granular soils, gravel, coarse sand etc. the capillary rise of water is almost negligible.

Depending upon the depth of the ground level, the treatment to be given to foundations depends upon condition of soils. Building foundations on ordinary soil where the sub-soil water table is not high are also liable to get damp. Bricks being porous, brick masonry below ground level can absorb moisture from adjacent ground. This moisture travels up from one course to another by capillary action and can make the wall damp for a considerable height. Providing DPC at appropriate place can check this.

In case of building constructed on damp soil in wet areas, both the walls as well as the ground floor are liable to become damp due to capillary rise of moisture from ground. In such cases, the DPC. is laid over the entire area of ground floor including wall thickness. Bitumen felts can be used for damp-proofing treatment. Immediately after laying the DPC is protected with a course of bricks laid flat on a cushion of fine sand.

Foundation rain water may also receive water percolating from adjacent ground and this moisture may rise in the wall. This can be checked by providing air drain parallel to external wall. The width of air drain may be about 20 to 30 cm. The outer wall of the drain is kept above the ground to check the entry of surface water. A concrete slab is provided at the top of the drain. Opening and gratings are provided at regular interval, for the passage of the air. Usually, DPC is also provided horizontally and vertically as shown in Figure 3.2.

Figure 3.2 : Air Drain

Where the foundations of basements are not properly drained (in dry or peat soil) and hence subjected to great hydrostatic pressure, then in such cases the structure should be disconnected from the face of the ground excavation and a trench made all round for width of about 30 cm taken down to a point as low as underside of the concrete footing (Figure 3.3). This becomes essential, because the mere provision of continuous DPC may not give satisfactory results. The bed of the trench should be provided with a good slope at each end and the trench filled with coke, gravel or stone, graded with fines to fill the voids. Moreover, in such cases the basement is relieved of hydrostatic pressure by suitably draining the sub-soil water. Providing open jointed land drain at the bottom of trench may drain sub-soil water and also drainage pipes below the concrete base.

Figure 3.3 : DPC Treatment of Foundation on Bad Soils

Treatment of Basements

To ensure the dryness, the whole of the structure below ground level should be provided with a continuous membrane of asphalt (i.e. DPC) either mastic asphalt or bituminous felt supported on the inside. This is achieved by spreading a layer of an impervious material (i.e. DPC) over the whole area of the floor and continuing the same through the horizontal walls extending vertically up, forming a sort of water proof tank as shown in Figure 3.4.

Figure 3.4 : Asphalt Tanking for Basement

Treatment to Floors

In places where the soil water table is low and rainfall is not much, a 75 to 100 mm thick layer of coarse sand is first spread over the entire area of flooring on the prepared bed of rammed earth. Alternatively, this layer can comprise stone soling with voids filled with smaller stones. This layer is known as base course and its material is well rammed. A 75 to 100 mm thick layer of lean cement concrete (1 : 3 : 6 or 1 : 4 : 8) mix or lime concrete is thereafter laid over the base course. This follows the base for the floor topping, which may comprise tiles, stone or cement concrete etc. In places where the sub soil water table is high, or in damp or humid areas, where there is possibility of moisture rising up in the floors, it is necessary to provide membrane DPC of flexible material like bitumen felt etc. over the entire area of flooring (Figure 3.5).

Figure 3.5 : DPC for Flooring

Treatment to Walls

Wall can get damp due to penetration of moisture from its external face to internal one, due to porosity of bricks and mortar joints. Various treatments given to exposed surface of walls to prevent dampness include pointing, plastering, painting etc. It is observed that plaster made out of cement, lime and sand mixed in proportion of 1 : 1 : 6 serves as protection of walls against dampness in weather conditions. In areas of heavy rainfall, cement plaster 1 : 4 (1 cement : 4 sand) mixed with water proofing compounds like Pudlo, Permo etc. serves the purpose effectively. In exposed brick work, dampness can be prevented by painting the surface with water proof cement paint. The provision of DPC for internal wall is shown in Figure 3.6.

Figure 3.6 : DPC for Internal Wall

Treatment to Roofs

Flat roofs require relatively heavier and costlier water-proofing treatment as compared with pitched or sloped roofs. The specification of material used for the purpose should be such that it performs the function of water-proofing as well as provides adequate thermal insulation. Stagnation of water on the roof is considered to be the root cause of leakage and dampness in flat roofs. This can be avoided by providing adequate roof slope and rainwater pipes. In case of RCC or RBC slab roofing with proper grading above, a slope of 1 in 40 to 1 in 60 is desirable. In addition to the slope, the size and the spacing of the rain water pipes or the outlets require due consideration for the proper drainage of the roof. In general practice, one 10 cm diameter pipe is considered suitable for every 30 square meter of the roof area to be drained. The water proofing of flat roofs are shown in Figure 3.7 and Figure 3.8.

Figure 3.7 : Water Proofing of Flat Roofs

Figure 3.8 : Water Proofing of Flat Roof Using Mastic Asphalt

The water proofing treatment for the roof may consist in laying bitumen felt directly over the surface of roof slab after painting the rooftop with hot bitumen. The bitumen felt may be hessian based or fibre based. Depending upon the type of building, climate and atmospheric conditions of the site, the treatment with felts may be with four courses, six courses or eight courses. The four-course treatment is recommended for moderate conditions, whereas the six and eight course treatments are recommended for severe and very severe conditions respectively. Learner can refer standard text for details about four or six course treatment and treatment of sloping roof.

SAQ 3

(a) What are the requirement of an ideal damp proofing materials?

(b) Discuss the characteristics of material commonly used as a damp proofing course (DPC) or in damp proof construction.

(c) Describe various methods of damp proofing.

(d) What problems are normally created by dampness in buildings and why? Mention possible remedies that you would recommend.

3.9 SUMMARY

In this unit, we have studied about termites and their effects, types of anti-termite treatment required for various components of buildings before as well as post construction.

Dampness is the presence of hygroscopic or gravitational moisture. Dampness in building gives rise to unhygienic conditions apart from reduction in strength of structural components of the building. We have understood about damp proofing and water proofing, sources and effects of dampness and precautions to be taken to prevent dampness in the buildings. Methods and materials used for damp proofing along with the damp proofing treatment essential for different components of a building have also been discussed.

Details pertaining to lintels, arches and scaffolding form the subject matter of next unit.

3.10 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section 'Further Reading' given at the end to get the answer of the SAQs.

UNIT 4 LINTELS, ARCHES AND SCAFFOLDING

Structure

4.1 INTRODUCTION

Openings are invariably left in the wall for the provision of doors, windows, cupboards, almirahs, wardrobes, etc. These openings are bridged by the provision of either a *lintel* or an *arch*. Thus, both lintels as well as arch are structural members designed to support the loads of the portion of the wall situated above the openings, and then transmit the load to the adjacent wall portions (jambs) over which these are supported. In this unit, we shall discuss lintels and arches, their types and material used for their construction.

We shall also discuss about *scaffolding*, which is a temporary structure constructed of timber or steel framework when the height of wall or column or other structural member of a building exceeds about 1.5 m. These temporary structures are needed to support the platform over which the workmen can sit and carry on the constructions.

Objectives

After studying this unit, you should be able to understand and familiarize

- describe lintels and their types,
- explain arches, various terms associated with an arch, and different types of arch,
- discuss stability of an arch and construction of arches, and
- describe scaffolding, its components and its different types.

4.2 LINTEL

A *lintel* is a horizontal member, which is fixed over the opening, viz., doors, windows recesses, etc. to support the structure over the opening. Lintels are thus a sort of rectangular beam which afford facilities for fixing the door and window frames, wherever they are used. Lintels may be made of several materials such as wood, stone, brick, reinforced brickwork, reinforced concrete or rolled steel sections embedded in cement concrete.

The width of lintel should be equal to the width of the wall. A proper bearing of lintel ends on supports is very essential. As a general rule, the bearing of the lintel at its ends should be either 10 cm or 4.0 cm for every 30 cm of span, whichever is greater. For very long spans, the bearing to the lintel ends should at least be equal to the depth of the lintel. Further, as a rule, the depth of the lintel can be adopted as $1/12^{th}$ of the span or 15 cm whichever is greater. The depth can be adjusted to course heights of brick or stone. The lintels should be strong enough to resist failure due to the forces of compression, tension and shear.

4.3 CLASSIFICATION OF LINTELS

Lintels are classified into the following types, according to the materials of their construction :

(a) Wooden lintels

(b) Stone lintels

(c) Brick lintels

(d) Reinforced concrete lintels

(e) Steel lintels

Wooden Lintels

Wooden lintels are oldest types of lintels. These lintels are not very common except in hilly areas. Wooden lintels are relatively costlier, structurally weak and vulnerable to fire. They are also liable to decay if not properly ventilated. Figure 4.1 shows a wooden lintel provided over the full width of the wall, by jointing together three wooden pieces with the help of steel bolts. Sometimes, wooden lintels are strengthened by the provision of mild steel plates at their top and bottom, such lintels are called *flitched lintels.*

Figure 4.1 : Wooden Lintel

Stone Lintels

A stone lintel consists of a simple stone slab of greater thickness. Stone lintels can also be provided over openings in brick walls. Stone lintels are the mostly used at the places, where stone is abundantly available. Dressed stone lintels give good architectural appearance.

Stone lintels are constructed of slabs of stones of sufficient length without flaws either in single piece or combination of more pieces. The thickness of the stone lintel should be 80 cm, or 4 cm for every 30 cm span, whichever is more. Stone is very weak in tension. Also, it cracks if subjected to vibratory loads. Hence stone lintels should be used with caution where shock waves are quite common.

Figure 4.2 : Stone Lintel

Brick Lintels

For openings lesser than 1 m and for lighter loads, lintels made from bricks are used. These are not very strong from structural point of view. A brick lintel consists of bricks placed on end or edge, as shown in Figure 4.3. The depth of brick lintel varies from 10 to 20 cm, depending upon the span. It is constructed over temporary wooden centering. The bricks with frogs are more suitable for the construction of lintel, since the frogs, when filled with mortar, form joggles which increase the shear resistance of end joints. Such lintel is known *as joggled brick lintel*.

Figure 4.3 : Brick Lintel

Reinforced Brick Lintel

Reinforced brick lintels are constructed at places where loads are heavy, or span is more. The depth of such lintel is kept equal to 10 cm, or in multiple of 10 cm. Sometimes, a 15 cm thick brick lintel may be obtained by using 5 cm thick tiles in conjunction with 10 cm thick bricks. Alternatively, bricks can be placed on edge. The bricks are so arranged that 2 to 3 cm wide space is left length-wise between adjacent bricks for the insertion of reinforcement of mild steel bars and the gap is filled with cement mortar. Vertical shear stirrups of 6 mm diameter wire are provided in every third vertical joint.

Figure 4.4 : Reinforced Brick Lintel

Main reinforcement having 8 to 10 mm diameter bars are provided at the bottom of the lintel.

Steel Lintels

Where the opening is large and the super-imposed loads are heavy, lintels made from steel are used. This type of lintel consists of rolled steel joists or channel sections either used singly or in combination of two or three units. When a single joist is used, it is either embedded in concrete, or cladded with stone facing, so as to increase its width to match with the width of the wall. When more than one unit is placed side by side, they are kept in position by pipe separators (Figure 4.5).

Figure 4.5 : Steel Lintels

Reinforced Cement Concrete Lintels

Reinforced cement concrete lintels are the most commonly used these days. They have replaced all other types of lintels because of their strength, rigidity, fire resistance, economy and ease in construction. These can be used on any span. Its width is kept equal to the width of the wall. The depth of RCC lintel and the reinforcement depends upon the span and the magnitude of loading. Longitudinal reinforcement, consisting of mild steel bars are provided near the bottom of lintel to take up tensile stresses. Half these bars, are however cranked up near the ends. Shear stirrups are provided to resist transverse shear. A typical RCC lintel is shown in Figure 4.6. RCC lintel over a window, along with a chhajja projection is shown in Figure 4.7. Formwork is required for construction of cast in-situ lintels. RCC lintels are also available as pre-cast units.

Figure 4.6 : RCC Lintel

Figure 4.7 : RCC Lintel with Chhajja Projection

SAQ 1

(a) Define lintel and classify various types of lintels.

(b) Explain the details of an RCC lintel having chajja projection by means of a neat sketch.

(c) Describe the reasons for RCC lintels having practically replaced all other materials used for lintels.

4.4 ARCH

An arch is a structure constructed of wedge-shaped units (bricks or stone), jointed together with mortar and spanning an opening to support the weight of the wall above it along with other super-imposed loads. Due to wedge-like form, the units support each other, the load tends to make them compact and enables them to transmit the pressure downwards to their supports.

In common with lintels, the function of an arch is to carry the weight of the structure above the opening. Lintels are simple and easy to construct, while special centering formwork is required for the construction of an arch. However, arches are constructed where loads are heavy, span is more, strong abutments are available and special architectural appearance is required.

Figure 4.8 : Elements of an Arch

4.4.1 Technical Terms

Most of the technical terms generally used in connection with the arch work are illustrated in Figure 4.8 and are briefly described below :

Abutment

This is the end support of an arch.

Pier

This is an intermediate support of an arcade.

Intrados

This is the inner curve of an arch.

Soffit

It is the inner surface of an arch. Sometimes, intrados and soffit are used synonymously.

Extrados

It is the upper or external curve of an arch.

Voussoirs

These are wedge-shaped or tapered units of bricks, stones or concrete works, forming the courses of an arch.

Crown

It is the highest part of extrados of an arch.

Key

It is the wedge-shaped unit fixed at the crown of the arch.

Spandril

This is a curved-triangular space formed between the extrados and the horizontal line through the crown.

Skew Back

This is the inclined or splayed surface on the abutment, which is so prepared to receive the arch and from which the arch springs.

Springing Points

These are the points from which the curve of the arch springs.

Springing Line

It is an imaginary line joining the springing and points of either end.

Pringer

It is the first voussoir at springing level; it is immediately adjacent to the skewback.

Arcade

It is a row of arches supporting a wall above and being supported by piers.

Haunch

It is the lower half portion of the arch between the crown and the skew-back or springer.

Ring

It is a circular course forming an arch. An arch may be made of one ring or more than one ring.

Impost

It is the projecting course at the upper part of a pier or abutment to stress the springing line.

Bed Joints

These are the joints between the voussoirs, which radiate from the centre.

Centre or Striking Point

This is the geometrical centre point from where the arcs forming the extrados, arch rings and intrados are described or struck.

Span

It is the clear horizontal distance between the supports or springing points.

Rise

It is the clear vertical distance between the springing line and the highest point on the intrados.

Depth or Height

It is the perpendicular distance between the intrados and extrados.

Thickness (or Breadth of Soffit)

This is the horizontal distance measured perpendicular to the front and back faces of an arch.

4.4.2 Stability of an Arch

The stability of an arch depends on the friction between the surfaces of wedge-shaped blocks called voussoirs and the cohesion of mortar. Every element of arch remains in compression. It has also to bear transverse shear. An arch may, therefore, fail in the following ways :

(a) Crushing of the arch material.

(b) Sliding of wedge-shaped blocks or voussoirs.

(c) Rotation or overturning of some joint about an edge.

(d) Differential settlement of supports or abutment/pier.

If the compressive stress or thrust exceeds the safe crushing strength of the materials, the arch will fail in crushing. Hence, the material used for construction should be of adequate strength, and the size of voussoirs should be properly designed to bear the thrust transmitted through them. For small spans, the thickness of the arch ring is kept uniform from crown to the springing. As a rule, the thickness of the ring may be taken either 1/12th the span or as follows (for brickwork in cement mortar, 1 : 4). For span up to 1.5 m – 20 cm; spans between 1.5 to 4 m – 30 cm; spans between 4 to 7.5 m – 40 cm, for span more than 7.5 m, the thickness at springing may be increased by about 20% of the thickness at the crown. For arch work, only first class blocks should be used, and in case of large spans, the arches may be strengthened by steel reinforcement, so that the safe crushing strength is not exceeded.

Sometimes, voussoirs of variable heights are provided with less height near crown and more height at skew-back. To safeguard against sliding of voussoirs past each other due to transverse shear, the voussoirs of greater height should be provided. Also, the angle between the line of resistance of the arch and the normal to any point should be less than angle of internal friction. To prevent *Rotation*, the line of resistance is kept within intrados and extrados and the line of resistance or thrust should be made to cross the joint away from the edge to prevent the crushing of that edge. It should be within middle third of the arch height. The differential settlement of abutment may cause secondary stresses in the arch. Hence the abutment, which has ultimately to bear all the loads transferred to it through the arch, should be strong enough. Also, the arch should be symmetrical, so that unequal settlements of the two abutments is minimized.

4.5 CLASSIFICATION OF ARCHES

An arch can be classified according to

(a) shape formed by soffit or intrados,

(b) number of centres,

(c) workmanship, and

(d) materials of construction.

Classification according to Shape by Soffit or Intrados

According to this classification, arches may be of the following types :

Flat Arch

A flat arch has usually the angle formed by skewbacks as 60^{o} with horizontal, thus forming an equilateral triangle with intrados as the base. The intrados is apparently flat, but it is given a slight rise of camber of about 10 to 15 mm per meter width of opening to allow for small settlements. However, the extrados is kept horizontal and flat. Flat arches are used only for light loads, and for spans up to 1.5 m. The depth of the arch is generally kept equal to three or four courses of the brick.

Segmental Arch

This is the common type of arch used for buildings. The centre of arch lies below the springing line. The bed joints of the voussoirs radiate from the centre of the arch. The depth of segmental arches may be 20 cm, 30 cm or any multiple of half bricks according to the class of work, width of opening etc. The thrust transferred to the abutment is in an inclined direction.

Semi-circular Arch

The shape of the arch soffits is a semi-circle and hence named semi-circular arch. This is the modification of segmental arch in which the centre lies on the springing line. The thrust transferred to the abutments is perfectly in vertical direction since the skewback is horizontal.

Horse Shoe Arch

The arch has the shape of a horseshoe, incorporating more than a semi-circle. Such type of arch is provided mainly from architectural considerations.

Pointed Arch

This pointed arch is formed by the intersection of curves at the apex or crown. It consists of two arcs of circles meeting at the apex or crown. Because of the style of architecture, it is also known as Gothic arch. There are five forms of pointed arch viz., drop, equilateral, lancet, tudor and Venetian arch.

Venetian Arch

This is another form of pointed arch which has deeper depth at crown than at springings. It has four centres, all located on the springing line.

Florentine Arch

This is similar to venetian arch except that the intrados consists of a semi-circular curve. The arch has, thus, three centres, all located on the springing line.

Figure 4.9 : Type of Arches

Relieving Arch

This arch is constructed either on a flat arch or on a wooden lintel to provide greater strength. The ends of the relieving arch should be carried sufficiently into the abutments. The relieving arch makes it possible to replace the decayed lintel later, without disturbing the stability of the structure.

Stilted Arch

It consists of a semi-circular arch with two vertical portions at the springings. The centre of the arch lies on the horizontal line through the tops of the vertical portions.

Semi-elliptical Arch

This type of arch has the shape of a semi-ellipse and may have either three centres or five centres.

Classification Based on Number of Centres

On the basis of number of centres, the arches may be classified as :

One-centred Arches

These arches have one centre only. Segmental arches, semi-circular arch, flat arches, horse-shoe arch and stilted arches come under this category. Sometimes, a perfectly circular arch, known as bull's eye arch as shown in Figure 4.10(a), is provided for circular windows.

Figure 4.10 : Arches Based on Number of Centres

Two-centred Arches

These arches are of several types but the popular ones are pointed arches and florentine arch as shown in Figures 4.9(e) and (g).

Three-centred Arches

Elliptical arches come under this category. Figure 4.10(b) shows a three-centred arch.

Four-centred Arch

It has four centres. Venetian arch is a typical example of this type. Another examples are the Tudor arch as in Figure 4.10(c).

Five-centred Arch

This type of arch, having five centres, gives a good semi-elliptical shape as is shown by Figure 4.10(d).

Classification Based on Material and Workmanship

On the basis of material of construction and workmanship, arches may be classified as follows :

Stone arches

Rubble arch, ashlar arch.

Brick Arches

Rough arch, axed or rough-cut arch, gauged arch and purpose made arch.

Concrete Arches

Concrete block units arch, monolithic arch.

A brief description of the above types is given below.

Stone Arches

Depending upon workmanship, stone arches are of two types :

Rubble Arches

These arches are made of rubble stones which are hammer dressed, roughly to shape and size of voussoirs of the arch and fixed in cement mortar. In this type, all the stones used may not be of the same size and hence joints formed are thicker. Rubble masonry arch is comparatively weak and is used for comparatively inferior work. Rubble arches are used up to spans of 1 m. They are also used as relieving arches, over wooden lintels. Up to a depth (thickness) of 40 cm, these arches are constructed in one ring. For greater depths, rubble stones are laid in two rings in alternate course of headers and stretchers.

Figure 4.11 : Ashlar Stone Arches

Ashlar Arches

In this type, the stones are cut to proper shape of voussoirs, and are fully dressed, set in lime or cement joints with proper bed joints. Up to depth of 60 cm, the voussoirs are made of full thickness of the arch. Ashlar arches have a good appearance and are used for superior work. Figure 4.11 shows some details of semicircular, segmental and flat arches of ashlar stones.

Brick Arches

Brick arches may be classified as rough brick arches, axed or rough cut brick arches, gauged brick arches and purpose made brick arches, depending upon the nature of workmanship and quality of bricks used.

Rough Brick Arches

This type of arch is constructed with ordinary bricks, which have not been wedge-shaped and consequently the joints formed are wider at the extrados than the intrados. Due to this, the appearance of the arch is spoiled. Therefore, this type of arch is not used for exposed brick work.

Axed Brick Arches

In this arch, the ordinary bricks are roughly cut with a brick layer axe to form wedge-shaped voussoirs. Due to this the joints are of uniform thickness (3 to 6 mm) along the radial line. However, the appearance of the arch is not very pleasant because the bricks cut to wedge-shapes are not finely dressed.

(a) Rough Brick Arches **(b) Axed Brick Arch**

Figure 4.12 : Brick Arches

Gauged Brick Arch

This type of arch is constructed of bricks, which are prepared to exact size, and shape of voussoir by cutting it by means of wire saw. The surfaces of the bricks are fine dressed with the help of a file. For this, only soft brick (called *rubber bricks)* are used. The joints formed in gauged brick arch are fine, thin (1 to 1.5 mm) and truly radial. Lime putty is used for jointing. Figure 4.13(a) shows a gauged brick flat arch while Figure 4.13(b) shows gauged bricks semi-circular arch.

Purpose Made Bricks Arch

In superior type of arch work, the purpose-made bricks are used to get still fine and thin joints. For this work, putty lime (i.e. pure slacked lime) is used for binding the blocks.

(a) Flat Arch **(b) Semi-circular Arch**

Figure 4.13 : Gauged Bricks Arches

Concrete Arches

Concrete arches are classified into two classes viz., pre-cast concrete block arches and monolithic concrete arches.

Pre-cast Concrete Block Arches

For small openings in a building, arches are made from pre-cast concrete blocks, each block being cast in the mould to the exact shape and size of voussoirs. Special moulds are prepared for voussoirs, key block and skewbacks. Because of exact shape and size of blocks, good appearance of the arch is achieved. Also, joints, made of cement mortar, are quite thin. However, casting of blocks is costly, and such work is economical only when the number of arches is quite large. Cement concrete of 1 : 2 : 4 mix is usually used.

Monolithic Concrete Arches

These arches are constructed for roofing of buildings, culverts and bridges. Monolithic concrete arches are constructed from cast-in-situ concrete, either plain or reinforced, depending upon the span and magnitude of loading. These arches are quite suitable for larger span. The arch thickness is 15 cm for arches up to 3 m span. Formwork is used for casting the arch, and is removed only when the concrete has sufficiently hardened and gained strength. The curing is done for 2 to 4 weeks.

4.6 CONSTRUCTION OF ARCHES

The construction of arches of all the types of materials (i.e. bricks, stones concrete) is carried out in three steps :

(a) Installation of centering or formwork for arches.

(b) Actual laying of arch work or course work.

(c) Striking or removal of centering or formwork.

Installation of Centering for Arches

The construction of arches is commenced at their springing points and is brought up uniformly towards the crown, where the key block is finally inserted and fixed. Centering is the temporary structure required to support brick, stone or concrete arch during its construction, till it has gained sufficient strength. The centering is installed in such a way that its upper surface corresponds with the intrados of the arch. For minor works, centering may be made of mud masonry constructed to match with the inner soffit of the arch, and then plastered. This masonry is dismantled later when the arch has been constructed and cured.

The usual centering is made of timber or steel. Wooden centering is the simplest and cheapest, used for moderate span. It is easy to construct and easy to dismantle and it can be used several times. Figure 4.14 shows a thick wooden plank, with horizontal bottom and the upper surface shaped to the underside of the soffit. Such a plank is known as *centre or* turning piece. Its width is normally 10 cm, and is supported on vertical timber posts called props, with wooden wedges to tighten or loosen the centering.

Figure 4.14 : Timber Centering for Small Spans and Thinner Soffits

If the soffit is wider than 10 cm, two ribs, suitably spaced and suitably shaped at the top may be used. These ribs may be connected by 4 × 2 cm wooden section called *laggings.* At the ends, bearers, wedges and posts as shown in Figure 4.15 support the ribs. For very large spans and wider

Figure 4.15 : Timber Centering for Wider Soffits

soffits, a built up centering of cut wood ribs is used. The upper surface of the ribs is given the shape of the soffit of the arch. Laggings (or cross-battens) are nailed across the ribs at close intervals to support the voussoirs at its top. Ribs are kept 25 to 40 mm thick, with width varying from 20 to 30 cm. The distance between ribs depends upon the thickness of the wall supporting the arch. Braces and struts to strengthen them connect the ribs. Horizontal ties are provided at the lower ends of the ribs to prevent them from spreading. The ribs are supported on bearers, and a pair of folding wedges is provided at the top of each prop to tighten or loosen the centering (Figure 4.16).

Figure 4.16 : Centering for Wide Soffits and Bigger Spans

Actual Lying of Arch Work

After the erection or installation of centering, skewbacks are first prepared to receive voussoirs. Voussoirs are then arranged in proper and required forms, starting from skewbacks and proceeding towards the crown. Finally, key-stone is inserted so that all the voussoirs are locked in position. The voussoirs are bedded or laid in definite courses in sequence with radial joints to ensure strength and stability of the arch.

Striking or Removal of Centering

The centering used for construction of arches should be removed, only when the arch has developed sufficient strength. The centering must be eased two days before its removal so that the voussoirs may close in and compress the mortar, but the centering must be completely removed before any masonry is constructed on the top of the arch. It is essential because the removal of centering after the masonry construction may cause a small settlement of the arch, which in turn, may cause cracks in arch masonry and hence structural weakness. No load should be placed on the arch unless the centering has been removed.

For small spans, loosening the folding wedges does the removal of centering. When the span is more than 7.5 m, using sand boxes under the centering trusses, to avoid shocks, does lowering and removal of centering. A sand box, shown in Figure 4.17, is placed below the prop. Sand is filled in box with a plugged hole at its bottom. Prop rests on the steel plate placed on the top of sand. In order to lower the centering, plug is taken out due to which the sand flows out and lowers the prop gradually.

Figure 4.17 : Sand Box Method

SAQ 2

(a) What are the functions of Arches? Give relative merits of lintels over the arches.

(b) Describe various technical terms used in connection with the arch work with the help of a neat sketch.

(c) Write a brief note on the classification of arches and enumerate, with the help of sketches, various types of arches based on its shape.

(d) Explain the method of erection of centering for arch construction.

4.7 SCAFFOLDING

When the height of wall or column or other structural member of a building exceeds about 1.5 m, temporary structures are needed to support the platform over which the workmen can sit and carry on the constructions. These temporary structures, constructed very close to the wall, are in the form of timber or steel framework, commonly called *scaffolding*. Such scaffolding is also needed for the repairs or even demolition of a building. The scaffolding should be stable and should be strong enough to support workmen and other construction material placed on the platform supported by the scaffolding. The height of the scaffolding goes on increasing as the height of construction increases, as shown in Figure 4.18.

Scaffolding has the following components :

Standards

These are the vertical members of the framework, supported on the ground or drums, or embedded into the ground.

Ledgers

These are horizontal members, running parallel to the wall.

Braces

These are diagonal members fixed on standards.

Putlogs

These are transverse members, placed at right angles to the wall with one end supported on ledgers and other end on the wall.

Figure 4.18 : Bricklayer's Scaffolding

Transoms

These are those putlogs whose both ends are supported on ledgers.

Bridle

This is a member used to bridge a wall opening, which supports one end of putlog at the opening.

Boarding

These are horizontal platform to support workmen and material; these are supported on the putlogs.

Guard Rail

This is a rail, provided like a ledger, at the working level.

Toe Board

These are boards, placed parallel to ledgers, and supported on putlogs, to give protection at the level of working platform.

Various components or members of the scaffolding are secured by means of rope-lashings, nails bolts etc.

4.8 TYPES OF SCAFFOLDING

Different types of scaffolding are given in the following table :

1.	Single Scaffolding or Bricklayer's Scaffolding	5.	Suspended Scaffolding
2.	Double Scaffolding or Mason's Scaffolding	6.	Steel Scaffolding and Centering
3.	Ladder Scaffolding or Patented Scaffolding	7.	Trestle Scaffolding

4.	Cantilever Scaffolding or Needle Scaffolding	8.	Wooden Gantries

Single Scaffolding (Bricklayer's Scaffolding)

This is most commonly used in the construction of brickwork. In this type of scaffolding, most of the members except platforms are usually made of bamboos and poles. It consists of a single framework of standards, ledgers, putlogs etc., constructed parallel to the wall at a distance of about 1.20 meters. The standards are placed at 2 to 2.5 m interval. Ledgers connect the standards, and are provided at a vertical interval of 1.2 to 1.5 m. Putlogs are placed with one end on the ledgers and other end in the hole left in the wall, at an interval of 1.2 to 1.5 m. Guards, boarding and other members are placed as shown in Figure 4.18.

As the work proceeds, the platform is raised to higher levels by extending the standards by adding extra pieces, if necessary. The scaffolding will be removed after the pointing or plastering and whitewashing work is over. After removing the putlogs, the holes must be filled solid immediately. Such scaffolding is commonly used for bricklaying, and is also called *putlog scaffolding*.

Double or Mason's Scaffolding

This type of scaffolding is stronger than the single scaffolding and it is used in the construction of stone work. In stone masonry, it is very difficult to provide holes in the wall to support putlogs. In that case, more strong scaffolding is used consisting of *two rows* of scaffolding. Each row thus, forms a separate vertical framework. The first row is placed at 20 to 30 cm away from the wall, while the other framework is placed at 1 m distance from the first one. Putlogs are then supported on both the frames. Rakers and cross-braces are provided to make the scaffolding more stronger and stable. Such scaffolding is also called *independent scaffolding*.

Figure 4.19 : Mason's Scaffolding

Ladder Scaffolding or Patented Scaffolding

This is a modification over double scaffolding and can be easily assembled (Figure 4.20). Now-a-days, several patent ladder scaffoldings are available in the market. In this type, the working platforms are supported on brackets (with inner row of standards), which can be adjusted to any desired height. The various components of the scaffold are fastened to each other by means of bolts and screws.

Such patented scaffoldings are very suitable for light works such as exterior walls' paintings and decoration. Sometimes, the ladder scaffolding is provided with additional cross-pieces which can be tied to windows for stability.

Figure 4.20 : Ladder Scaffolding or Patented Scaffolding

Cantilever or Needle Scaffolding

The use of this type of scaffolding becomes necessary where :

(a) it is not possible to fix the standards into the ground in the usual manner,

(b) the scaffolding is to be provided on the side of a busy street without obstructing the traffic on road, and

(c) the scaffolding is required for construction of upper storeys of a tall building.

In this, framework whether of single scaffolding type or double scaffolding type is supported by a series of cantilevers or needle beams (i.e., timber beams projecting from wall) passing through window openings or through holes in the wall. In Figure 4.21, two alternatives of supporting the projecting end are shown. In first alternative, the needles are supported at floor levels inside by means of plate and wedges, and outside projecting end is strutted to the window sills or cornices or string courses etc. In the second alternative (shown by dotted lines), the projecting beams are strutted inside on floors through the openings. The strut ends on floors are held in position by means of blocks or suitable devices. The joints between the inclined strut and the needle are clamped by means of dogs.

Figure 4.21 : Cantilever or Needle Scaffolding

Suspended Scaffolding

This type of scaffolding is suitable for light steel frame construction as well as for maintenance works such as painting, pointing distempering, etc. In this type standards do not rest on the ground and hence scaffolding does not create any obstruction on the floor. The working platform is suspended from the roofs by means of wire ropes or chains. The mechanical arrangements are provided to raise or lower the platform to attain the optimum level for working.

Steel Scaffolding

Steel scaffolding is practically similar to timber scaffolding except that steel tubes replace wooden members and rope lashings are replaced by steel couplets or fittings. Such scaffolding can be erected and dismantled rapidly. It has greater strength, greater durability and higher fire resistance. Though its initial cost is more but its salvage value is higher. It is extensively used these days. Figure 4.22 shows steel scaffolding both for brick wall as well as stone wall.

Trestle Scaffolding

In this type, the working platforms are supported on the top of mobi1e devices, such as tripods, ladders, etc. mounted on boggies, wheels or lorries. Trestle scaffolding is suitable for minor repairs or painting work up to a maximum height of 5 m from the supporting level.

(a) For Brick Wall (Single Frame Type)

(b) For Stone Wall (Double Frame Type)

Figure 4.22 : Steel Scaffolding

Wooden Gantries

In construction operations, where structural materials are beyond the capacity of manual handling, the gantries are used. Gantries are provided with lifting tackle to handle heavy construction blocks, stones and other materials.

A gantry usually consists of timber staging (though steel staging can also be used) for carrying a traveling crane and is made of squared timbers in a similar manner as the masons' scaffolding. But, in this type, only one row of standards on either side of the wall is provided. On the top of the standards, longitudinal pieces called runners are provided along the wall, over which cross-pieces known as rails are provided to carry the traveling platform. Traveling platform in turn carries a lifting tackle moving on the rails in a direction perpendicular to the length of the gantry. This lifting tackle finally delivers the construction units at the desired height.

SAQ 3

(a) What do you understand by scaffolding? Mention its various components.

(b) Name the different types of scaffolding and describe any two with the help of neat sketches, which are most commonly used.

(c) Differentiate between brick layer’s scaffolding and Mason’s scaffolding.

(d) Write short notes on ladder scaffolding, needle scaffolding and wooden gantries.

4.9 SUMMARY

In this unit, we have studied about lintel, arches and scaffolding. Type of lintels and arches, type of scaffolding required for different stages of construction work is also discussed. We have also understood the necessity of lintels and arches in building construction and procedures for construction of lintels and arches. In the next unit, we will study different types of flooring.

4.10 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section ‘Further Reading’ given at the end to get the answer of the SAQs.

UNIT 5 FLOORINGS

Structure

5.1 INTRODUCTION

Floors are essential components of a building. These are horizontal elements which provide a level surface to support the occupants of a building, furniture, equipment and sometimes, internal partitions. In this unit, we shall discuss about ground floors, upper floors and their types, important factors effecting choice of floor and construction details of some of the important types of ground and upper floors.

Objectives

After studying this unit, you should be able to

- define floors and grasp the concept of ground and upper floors,
- list important factors affecting selection of floorings and floors,
- describe different materials used in construction of floors, and
- explain various types of flooring and their construction details.

5.2 FLOORS

Floors are horizontal elements of a building structure which provide a level surface to support the occupants of a building, furniture, equipment and sometimes, internal partitions. Floors are used to divide the building into different levels for the purpose of creating more accommodation within a restricted space one above the other. The floors resting directly on the ground surface are known as *ground floors,* while the other floors of each storey, situated above the ground level are known as *upper floors*.

A floor consists of the following two components :

A Sub-floor (or Base Course, or Floor Base)

> The purpose of this component is to impart strength and stability to support floor covering and all other superimposed loads. For ground floor, its purpose is also to prevent settlement and to provide damp resistance and thermal insulation.

Floor Covering (or Paving, or Flooring)

> This is the covering over the sub-floor and is meant to provide a hard, clean, smooth, impervious, durable and attractive surface to the floor.

5.3 GROUND FLOORS

The bottom floor near the ground level is termed as the ground floor. The function of the ground floor is to give clean, smooth, impervious, durable and a wear resisting surface. The problems of strength and stability are usually minor ones at ground since full support from the ground is available at all points. However, major problem of ground floors is *damp exclusion* and *thermal insulation*. Moisture is generally present in the ground, which may pass into the building through the floor unless measures are taken to check it.

The floors supported directly on the ground are known as ground floors. The floor base for a ground floor is shown in Figure 5.1. The lowest layer just above ground surface is that of compacted earth fill. The second layer may be either of lean cement concrete or lime concrete or sometimes broken brick bats or stone rammed properly. The third layer of cement concrete is more common since it gives proper rigidity to the floor base. Over this uniform and even surface or layers, a floor covering or flooring, i.e. wearing surface or finish is provided.

Figure 5.1 : Floor Base for a Ground Floor

To ensure proper drainage, a floor may consist of a system of drains constructed below it, such that the whole water leads outside the building. However in normal construction of ground floors, the space above the ground, up to a height about 25 to 30 cm below the plinth level is first filled up with inert material to prevent the rise of water into the floor. This porous layer of inert material may be made of materials, such as sand, gravel, crushed stone, cinder, etc.

5.3.1 Materials Used for Ground Floors

The materials generally used for ground floor construction are bricks, stones, wooden blocks and concrete. The materials employed for floor finishes or floorings are as follows :

(a)	Mud and muram	(i)	Marble
(b)	Bricks	(j)	Asphalt
(c)	Stones	(k)	Rubber
(d)	Wood and timber	(l)	Cork
(e)	Concrete	(m)	Glass
(f)	Terrazo	(n)	P.V.C. or Plastic
(g)	Mosaic	(o)	Magnesite
(h)	Tiles	(p)	Linoleum

5.3.2 Types of Ground Floorings

The various types of floorings used in the ground floor constructions, on the basis of materials used in their formation, are designated as below :

(a) Mud flooring and muram flooring

(b) Flag-stone flooring or stone flooring

(c) Brick flooring

(d) Timber flooring or wood-block flooring

(e) Cement concrete flooring

(f) Mosaic flooring or China mosaic flooring

(g) Terrazo flooring

(h) Granolithic flooring

(i) Tiled flooring

(j) Rubber flooring

(k) Linoleum flooring

(l) Cork flooring or cork tile flooring

(m) Magnesite flooring

(n) Glass flooring

(o) Marble flooring

(p) PVC or plastic flooring

(q) Asphalt floring or mosaic asphalt flooring

5.3.3 Factors Effecting Selection of Ground Floorings (or Wearing Surfaces)

Each type of floor has its own merits and there is not even a single type which can be suitably provided under all circumstances and more so when floors have to serve different purposes in different types of buildings, such as residential, institutional, industrial, assembly, etc. However, the selection of flooring, i.e. floor covering should be made considering the following factors:

Initial Cost

The cost of construction is very important item in the selection of a type of floor and floor covering, and it widely varies for different types. The floor coverings of marble, rubber tiles and special clay tiles are considered to be most expensive whereas the floorings, viz, Terrazzo, linoleum, cork, asphalt, tile, vinyl tile, slate, etc. are moderately expensive. The floors made of concrete and brick, offer the cheapest type of floor construction. It should be ensured during the comparison of cost for different floors, that the costs of both covering and sub-floor have been accounted. Hence, the se1ection of flooring should be made keeping in view the available funds for construction and utility of the building.

Appearance

Flooring should produce a desired colour effect and architectural beauty in conformity with the use of building. Generally, floorings of terrazzo, tiles, marble and cement mortar provide a good appearance whereas the asphalt covering gives an ugly appearance.

Cleanliness

Being the sanitation priority, a floor should be non-absorbent and capable of being easily and effectively cleaned. All joints in flooring should be such as to offer a water-tight surface. Moreover, greasy and oily substances should neither spoil the appearance nor should have a destroying effect on the flooring materials. For instance though floorings of terrazzo provide a good appearance yet are adversely affected by greasy substances. From the viewpoint of cleanliness, floorings of terrazzo, marble, tiles and slates are generally used.

Durability

The flooring material should offer sufficient resistance to wear and tear, temperature, chemical action etc., so as to provide long life to the floors, That is, the flooring should be strong enough to withstand the effects of anticipated traffic and other substances without undue deterioration. From durability point of view, the floorings of marble, terrazzo tiles and concrete are considered to be of best type. The floorings of other materials such as linoleum, rubber, cork tile, bricks, wood blocks, mastic asphalt, etc. can also be used where heavy floor traffic is not anticipated.

Damp-resistance (or Damp-proofing)

All the floors, especially ground floors, should offer sufficient resistance against dampness in buildings to ensure healthy environment. Normally, the floors of clay, tiles, terrazzo, concrete, bricks, etc. are preferred for use where the floors arc subjected to dampness. The use of flooring material, like wood, rubber, linoleum, cork, etc. should be avoided for floors in damp situations.

Sound Insulation (or Noiselessness)

According to modern building concepts, a floor should neither create noise when used nor should transmit noise, particularly in a vertical direction. In case of ground or basement floors, the sound vibrations are damped out because of the contact with the mass of the earth. Hence, it is more important a factor for upper floors, where they are supposed to act as horizontal barriers for the passage of sound in vertical direction. However, the flooring material should possibly be such that it either produces no noise or less noise when travelled over, specially for buildings such as libraries, hospitals, colleges, universities, theatres, etc. Cork tiles and rubber floorings provide excellent sound insulation properties whereas the floors of wood, linoleum, asphalt, etc. also serve this purpose satisfactorily.

Thermal Insulation

It should be possible for a building to maintain constant temperature or heat inside the building irrespective of the temperature changes outside. It is needed to reduce the demand of heating in winter and refrigeration in summer. It is especially important in case of wooden floors where heat losses are considerable and in solid floors with heating pipes or cables where the heat losses at the edges of floor slab can be higher. The floors of wood, rubber, cork, etc. are best suited for this purpose.

Smoothness

The floor covering should be of superior type so as to exhibit a smooth and even surface. But at the same time, it should not be too slippery, which will otherwise endanger the safe movements over it, particularly by the old people and the children. Floor coverings of tiles, terrazzo, concrete, etc. have better performance from this angle.

Hardness

It is desirable to use good quality floor coverings which do not give rise to any form of indentation marks, imprints etc., when either used for supporting the loads or moving the loads over them. Normally, the hard surfaces rendered by the concrete, marble, stone, etc. do not show any impressions whereas the coverings, like asphalt, rubber, cork, plastic etc., do form the marks on the surfaces when used by the traffic.

Comfort Criteria (i.e. Shock-Absorbing and Good Conductivity Properties)

The flooring material should be such that it gives comfort to the occupants, under living and working conditions. The use of flooring materials, like cork tiles, rubber, wooden blocks, linoleum, plastic, etc., is preferred from comfort viewpoint as they provide floors which are good conductors of heat. The floorings of concrete, terrazzo, marble, slate, brick, etc. are generally tiresome and cold, so do not offer comfort to the occupants.

Fire Resistance

This is relatively an important factor in the selection of upper floors which are required to act as highly resistant fire barrier between the different levels or a building. However, the flooring material should offer sufficient resistance to fire, in order to safeguard the life, activities, goods, etc. within a building. The floor covering should be made of fire-resistant or non-combustible materials such as concrete, bricks, clay tiles, marble, etc. The flooring of combustible materials like, cork, linoleum, plastic, etc. should be laid on fire-resistant base only.

Maintenance Considerations

It is always desired that the maintenance cost should be as low as possible. Generally, the coverings of tiles, marble, terrazzo and concrete, require less maintenance cost as compared to the floors of wood blocks, cork, mastic asphalt, etc. It should, however, be noted that the repairing of concrete surfaces is more difficult than the floorings of tiles, marbles, slates, etc.

5.3.4 Construction Details of Ground Floorings

A brief construction details of some of the important types of ground flooring is given below, and for others learner may refer any of the standard text on this subject.

Brick Flooring

This type of flooring is suitable for cheap construction, specially where good bricks are available. This flooring is specially suited to ware-houses, stores, godowns etc. Brick flooring is commonly used in alluvial places like UP, Punjab etc. Well-burnt bricks of good colour and uniform shapes are used. Bricks are laid either flat or on edge, arranged in herring hone fashion or set at right angles to the walls, or set any other good looking pattern (Figure 5.2).

Figure 5.2 : Brick Flooring

The method of preparing the base course for brick flooring varies from place to place. In one method, the sub-grade is compacted properly to the desired level, and a 7.5 cm thick layer of sand is spread. Over this, a course of bricks laid flat in mortar is built. This forms the base course, over which the brick flooring is laid in 12 mm thick bed of cement or lime mortar, in the desired pattern. In the second method, 10 to 15 cm thick layer of lean cement concrete (1: 8: 16) or lime concrete is laid over the prepared subgrade. This forms the base course, over which bricks are laid on edge (or flat) on 12 mm thick mortar bed in such a way that all the joints are full with mortar. In both the cases, the joints are rendered flush and finished. The work is then properly cured.

Cement Concrete Flooring

This type of flooring is most commonly used for residential, commercial and even industrial building, since it is moderately cheap, quite durable and easy to construct. This flooring is also known as Indian patent stone flooring. The floor consists of two components, which are :

(a) base concrete, and

(b) topping or wearing surface.

The two components of the floor can be constructed either monolithically (i.e. topping laid immediately after the base course is laid) or non-monolithically. When the floor is laid monolithically, good bond between the two components is obtained resulting in smaller overall thickness. However, such a construction has three disadvantages. These are

(a) the topping is damaged during subsequent operations,

(b) hair cracks are developed because of the settlement of freshly laid base course which has not set, and

(c) work progress is slow because the workman has to wait at least till the initial setting of the base course.

Hence in most of the cases, non-monolithic construction is preferred.

First of all, the surface of the ground for receiving the floor is leveled, well-watered and rammed. Upon the above prepared surface of the ground, a 15 cm thick layer of broken stones or hard bricks is evenly spread and consolidated, provided that the ground is made up of loose or soft soil. This sub-base or subgrade so prepared is also called as hard core. Thereafter, a layer of lime concrete (1 : 2 : 4), about 15 cm thick is laid on the hard core or directly on the surface of the ground if made up of good soil. Necessary slope is given to the surfaces of lime concrete. To facilitate the washing down of the finished floor; usually a slope 1 in 120 to 1 in 240, is sufficient for inside floors and a outward slope of 1 in 36 to 1 in 40 is recommended for bath rooms and verandah floors. The lime concrete layer should be watered and well rammed for two days and on the third day the topping concrete should be laid.

When the base concrete has hardened, its surface is brushed with stiff broom arid cleaned thoroughly. It is wetted the previous night and excess water is grained. The topping is then laid in square or rectangular panels, by use of either glass or plain asbestos strips or by use of wooden battens set on mortar bed. The panels may be 1 × 1 m, 2 × 2 m or 1 × 2 m in size. The topping consists of 1 : 2 : 4 cement concrete, laid to the desired thickness (usually 4 cm) in one single operation in the panel. Alternate panels are laid first. Prior to laying the concrete in the panel, a coat of neat cement slurry is applied. This cement slurry laid on rough finished base course ensures proper bond of topping with the base course. Glass strips or battens should have depth equal to thickness of topping. Topping concrete is spread evenly with the help of a straight edge, and its surface is thoroughly tamped and floated with wooden floates till the cream of concrete comes at the top. Steel trowel is used for smoothing and finishing the top surface. Further troweling is done when the mix has stiffened. Dusting of the surface with neat cement and then troweling results in smooth finish at the top. Other alternate layers are then laid after 72 hours, so that initial shrinkage of already laid panels take place, thus eliminating the cracks. The prepared surface is protected from sunlight, rain and other damages for 12 to 20 hours. The surface is then properly cured for a period of 7 to 14 days. When monolithic construction is laid, the topping is laid 1 hour to 4 hours after placing the base concrete. Figure 5.3 shows details of concrete flooring.

Figure 5.3 : Concrete Flooring Details

Granolithic Flooring

In industrial building, hard wearing surface is sometimes required. This can be achieved by applying granolithic finish over the concrete topping described above. Granolithic finish consists of rich concrete made with very hard and tough quality coarse aggregate (such as granite, basalt, quartzite etc.) graded from 13 to 240 no. I.S. sieve. The concrete mix proportion varies from 1 : 1 : 2 to 1 : 1 : 3 for heavy duty floors to 1 : 2 : 3 for public buildings. The thickness of finish may be minimum 25 mm when laid monolithically with the top concrete, and 35 mm when laid over hardened surface. However, for public buildings such as schools, hospitals etc. the thickness of the finish may be 13 mm to 20 mm using small size aggregate; If exceptionally hard surface is required, sand may be replaced by fine aggregate of crushed granite, and/or abrasive grit may be sprinkled uniformly over the surface at the rate of 1.5 to 2.5 kg/sq m, during floating operation.

Terrazzo Flooring

This is a special type of concrete flooring in which marble chips are used as aggregates and this concrete on polishing with carborundum stone presents a smooth surface. It is very decorative and has good wearing properties. Due to this, it is widely used in residential buildings, hospitals, offices, schools and other public buildings. *Terrazzo* is a specially prepared concrete surface containing cement (white or grey) and marble chips (of different colours), in proportion to 1 : 2 to 1 : 3, when the surface has set, the chips are exposed by grinding operation. Marble chips may vary from 2 mm to 8 mm size. Colour can be mixed to white cement to set desired tint. The flooring is, however, more expensive.

The sub-base preparation and concrete base laying is done in a similar manner, as explained for cement concrete flooring. The top layer may have about 40 mm thickness, consisting of

(a) 34 mm thick cement concrete layer (1 : 2 : 4) laid over the base concrete, and

(b) about 6 mm thick terrazzo topping.

Before laying the flooring; the entire area is divided into suitable panels of predetermined size and shape. For this, aluminum or glass strips are used. The strips have the same height as the thickness of the flooring (i.e. 40 mm). The strips are jointed to the base concrete, with the help of cement mortar, and their tops are perfectly set to level and line. Alternate panels are filled. The width of the strips may be 1.5 to 2.0 mm.

The surface of base concrete is cleaned of dirt etc. and thoroughly wetted. The wet surface of the base concrete is smeared with cement slurry. Concrete of grade 1 : 2 : 4 is then laid in alternate panels levelled and finished to rough surface. When the surface is hardened, the terrazzo mix (containing cement, marble chips and water) is laid and finished to the level surface. Additional marble chips may be added during tamping and rolling operation, so that atleast 85% of the finished surface show exposed marble chips. The surface is then floated and trowelled, and left to dry for 12 to 20 hours. After that, the surface is cured properly for two to three days.

The first grinding is done, preferably by machine, using coarse grade (No. 60) carborundum stones, using plenty of water. The ground surface is then scrabbed and cleaned. Cement grout of cream like consistency, of the same colour, is then applied on the surface so that pores and holes etc. are filled. The surface is cured for 7 days and then second grinding is done with carborundum stones of fine grade (No. 120). The surface is scrabbed and cleaned thoroughly, and cement grout is again applied. The surface is cured for 4 to 6 days and final grinding is done with carborundum stones of 320 grit size. The surface is thoroughly scrabbed and cleaned, using plenty of water. The floor is then washed with dilute oxalic acid solution. Finally, the floor is polished, with polishing machines the wheels of which are fitted with felt or hessian bobs, to get fine shine. Wax polish is also applied with the help of the polishing machine, to get final glossy surface.

Mosaic Flooring

Mosaic flooring is made of small pieces of broken tiles of china glazed or of cement, or of marble, arranged in different patterns. These pieces are cut to desired shapes and sizes. A concrete base is prepared as in the case of concrete flooring, and over it 5 to 8 cm thick lime-surkhi mortar is spread and leveled over an area which can be completed conveniently within working period so that the mortar may not get dried before the floor is finished. On this, a 3 mm thick cementing material, in the form of paste of two parts of slaked lime, one part of powdered marble and one part of puzzolana material, is spread and is left to dry for about 4 hours. Thereafter, small pieces of broken tiles or marble pieces of different colours are arranged in definite patterns and hammered into the cementing layer. The surface is gently rolled by a stone roller of 30 cm diameter and 40 to 60 cm long, sprinkling water over the surface, so that cementing material comes up through the joints, and an even surface is obtained. The surface is allowed to dry for 1 day, and thereafter, rubbed with a pumice stone fitted with a long wooden handle, to get smooth and polished surface. The floor is allowed to dry for two weeks before use.

Tiled Flooring

Tiles, either of clay (pottery) or cement concrete or terrazzo, are manufactured in square, hexagonal or other shapes, sizes and thickness these days. These are commonly used in residential houses, offices, schools, hospitals and other public buildings, as an alternative to *terazzo* flooring, especially where the floor is to be laid quickly. The method of laying tiled flooring is similar to that for flag stone flooring except that greater care is required. Over the concrete base, a 25 to 30 mm thick layer of lime mortar 1: 3 (1 lime and 3 sand or surkhi) is spread to serve as bedding. This bedding mortar is allowed to harden for 12 to 24 hours. Before laying the tiles, neat cement slurry is spread over the bedding mortar and the tiles are laid flat over it, gently pressing them into the bedding mortar with the help of wooden mallet, till levelled surface is obtained. Before laying the tiles, thin paste of cement is applied on their sides, so that the tiles have a thin coat of cement mortar over the entire perimeter surface. Subsequently on the next day, the joints between adjacent tiles are cleaned of loose mortar etc. to a depth of 5 mm, using wire brush, and then grouted with cement slurry / of the same colour shade as that of the tiles. The slurry is also applied over the flooring in thin coat. The flooring is then cured for 7 days, and then grinding and polishing is done in the same manner as that for terrazzo flooring.

Marble Flooring

It is a superior type of flooring, used in bath-rooms and kitchens of residential buildings, and in hospitals, sanatoriums and temples etc. where extra cleanliness is an essential requirement. Marble slabs may be laid in different sizes, usually in rectangular or square shapes. The base concrete is prepared in the same manner as that for concrete flooring. Over the base concrete, 20 mm thick bedding mortar of either 1 : 4 cement: sand mix or 1 (lime putty) : 1 (surkhi) : 1 coarse sand mix is spread under the area of each individual slab. The marble slab is then laid over it, gently pressed with wooden mallet and levelled. The marble slab is then again lifted up, and fresh mortar is added to the hollows of the bedding mortar. The mortar is allowed to harden slightly, cement slurry is spread over it, the edges of already laid slabs are smeared with cement slurry paste, and then the marble slab in question is placed in position. It is gently pushed with wooden mallet so that cement pastes ooze out from the joint which should be as thin as possible (paper thick). Then oozed out cement is cleaned with cloth. The paved area is properly cured for about a week.

Cork Flooring

Such type of flooring is perfectly noiseless, and is used in libraries, theatres, art galleries, broadcasting stations etc. Cork, which is the outer bark of cork oak tree, is available in the form of cork carpet and cork tiles. It is fixed to concrete base by inserting a layer of saturated felt. Cork carpet is manufactured by heating granules of cork with linseed oil and compressing it by rolling on canvass. Cork tiles are manufactured from high grade cork bar or shearings compressed in moulds to a thickness of 12 mm and baked subsequently. They are available in various sizes (10 cm × 10 cm to 30 cm × 90 cm), various thicknesses (5 to 15 mm) and various shades.

Glass Flooring

This is special purpose flooring used in circumstances where it is desired to transmit light from upper floor to lower floor, and specially to admit light at the basement from the upper floor. In general, this type of flooring is not commonly used for floors. For the construction of glass flooring, structural glass is available in the form of tiles or slabs, in thicknesses varying from 10 to 30 mm. These are fixed in closely spaced frames so that glass and the frame can sustain anticipated loads. Glass flooring is very costly, and is not commonly used.

SAQ 1

(a) Differentiate between floors and floorings. List the various types of floorings or floor finishes used for ground floor construction. Also discuss the various factors you would consider in their choice or selection.

(b) Explain the procedure of constructing the following types of flooring :

- (i) Terrazo Flooring
- (ii) Cement concrete flooring
- (iii) Mosaic flooring

(c) What type of flooring or ground floor do you recommend for the following? Explain with reasons.

- (i) Operation theatre
- (ii) Dancing hall
- (iii) High class hotel.

5.4 UPPER FLOORS

The upper floors, in addition to having a good wearing surface, should be stronger to sustain heavier loads and should provide adequate sound insulation and fire resistance in buildings. To perform these functions effectively, the following factors require due consideration in the selection of type of construction for upper floors in a building.

5.4.1 Materials Used for Upper Floors

The materials generally used for upper floor construction are same as used for ground floors. Apart from bricks, stones, wooden blocks and concrete, rolled steel joists (RSJ) are also used for some types of upper floors.

5.4.2 Types of Upper Floors

The upper floors are generally classified on the basis of arrangement of beams and girders, or the framework, for supporting the flooring and the materials used in the entire floor construction. The various types of upper floors commonly used are as follows :

(a) Timber floors

(b) Steel joists and flag stones, or precast concrete slabs floor

(c) Jack arch floors

(d) Reinforced Brick Flooring

(e) Reinforced Cement Concrete (RCC) floor

(f) Ribbed or hollow tiled flooring

(g) Filler joists floors

(h) Pre-cast concrete floors

5.4.3 Important Factors Effecting Construction of Upper Floors

The relative importance of above mentioned factors varies with different categories of buildings. Sometimes, in addition to the above factors, local conditions, viz., prevailing construction practices; availability of labour, machines and materials, climatic conditions (hot dry, hot humid, etc. in India), completion time limit, etc. also govern the selection of type of construction, some of which are described below.

Initial Cost

It is one of the most important factors in selecting a specific floor system and wearing surface. For cost analysis of different floor systems, three costs, namely direct costs, indirect costs and annual cost of maintenance and operations, should be considered. The **direct costs** include the cost of floor system, including the wearing surface, the supporting beams, and curing surfaces whether directly applied or suspended. The **indirect costs** are the costs of girders, the columns and their foundations, and sometimes the increased height also which may be needed for thicker or heavier floorings.

The effect of **annual cost** of maintenance and operation on various alternate wearing surface should also be accounted in cost analysis. In multi-storied buildings, the installation of fire-fighting equipment, like automatic sprinkler systems, may make changes in the type of construction and reduce the overall cost. Because of numerous factors, including building code requirements, and relative availability and costs of different kinds of equipment, labour and materials, no specific comparisons can be arrived at. For example, wooden floors may be costlier at places where timber is not available, but it may be cheaper than concrete floors where it is available in abundance, e.g. in hilly regions.

General Type of Building Construction

The floor system and the structural frame are so interlinked that the selection of basic materials and types of construction are made for the building as a whole. For a given building, several alternatives are analysed in view of building code requirements, intended functions, performance and economy.

Based on the analysis, the following combinations are generally suggested :

(a) If columns, beams and girders are made of wood, then a timber or wood floor system should be used.

(b) If building is made of steel framed type, then the floor system can be of plain concrete type, RCC type or RCC ribbed floor type.

(c) If building is made of R.C.C. framed type, then the floor system will be either of plain concrete or RCC slab or RCC ribbed floor.

(d) If building consists of masonry bearing walls, then the various floor systems such as timber floors, concrete floors, steel joists or I beams, RCC beams and slabs, precast concrete, etc. can be used.

Amount and Type of Floor Loading (or Floor Loads)

The intensity of loading and type of loading (whether uniformly distributed or concentrated) are important considerations from the viewpoint of safety, functional performance and economy of a building. For example, a flat slab floor construction is economical for heavy uniformly distributed loading because in beam and slab floor construction, very deep beams may be required. In case of heavy concentrated loads, a diagonal beam floor should be selected as it will distribute the load equally throughout the members of the grid.

Generally, any type of floor can be selected for light loads, but for medium and heavy loads the following floor systems are suggested :

(a) Steel joists with RCC slabs

(b) RCC slabs

(c) Steel joist with timber decks

(d) Double joist timber floors

Plan of Building

The floor system sometimes is fixed by the plan requirements of a building. The economic ranges of various types of floor systems depends upon the span range and loading on the floor. For span varying 3 m to 6 m and loads up to 200 kg/sq.m., timber floor are appropriate. For higher loads up to 200-400 kg/sq.m., and over 400 kg/sq.m., RCC floors are preferred.

Function or Use of Building

The use to which a building is to be put determines the general type of construction. This, in turn, is interrelated to the floor system as discussed earlier. Moreover, the floor type depends upon loading, degree of fire resistance, degree of sound insulation, etc. required for specific use of a building.

Weight and Position of Floor

The weight of a floor system to carry a given load is an important factor, because it affects the cost of super-structure and foundations. Timber floors are suitable where its use is permissible. Floor systems with thin lightweight slabs with closely spaced joists are preferred. The use of lightweight and cellular concrete can also help in reduction of weight, etc.

Position of floors, i.e., ground, Ist floor, 2nd floor, etc. also affects the choice of type of construction. Ground or basement floors are normally made of concrete slabs and when subjected to hydrostatic pressure may have light mesh reinforcement.

Fire Resistance

Floors should act as horizontal barriers against the passage of fire and hence, should be constructed of fire-resistance materials. The following types of floor construction are suggested in general for different types of buildings.

(a) Ordinary wooden joist floors can be economically used for residential buildings where fire-resistance is not a decisive factor.

(b) Heavy timber construction can be economically used for buildings, such as warehouses and other industrial buildings where sufficient degree of resistance is desired. This is especially true when automatic sprinkler systems are installed, for such buildings, the fire-resistive construction may prove to be costlier.

(c) Fire-resistive construction, and floors constructed to open web steel joists and concrete slabs protected with suspended ceilings of metal lath or gypsum plaster, are recommended for multi-storeyed and fire-hazardous buildings in congested cities. Moreover, the coarse aggregate in concrete would be of foamed slag, pumice, blast furnace slag, crushed brick and burnt clay products, etc. which offer sufficient fire resistance.

Sound Insulation

The degree of sound insulation required is different for different types of buildings. Therefore, the different systems of floors with varying degree of sound insulation are used as per the requirements. Sound transmission of impact noises is influenced by the floor system as well as the type of wearing surface. The following types of floor construction are suggested, according to the degree of insulation against air-borne sound and impact sound (i.e. structure-borne-sound).

(a) A solid concrete floor of sufficient thickness and weight offers sufficient insulation against air-borne sound. It should be noted that greater the weight of structure, greater will be the insulation against air-borne sound. The wearing surface or floor finish over this floor, if consists of carpet, cork, tile, rubber etc. will provide insulation against impact or structure-borne sound. A floating floor on top or suspended ceiling underneath is also used for insulation against impact sound.

(b) The use of light-weight concrete or cellular concrete is also common for floor construction against air-borne sound. The use of fibrous and resilient materials in floor construction also offers good sound insulation.

(c) The blocked timber floors offer little insulation which is generally acceptable in the first floor of the building. Sound insulation should be effectively provided in case of film studios of the radio stations, hospitals, educational institutes, hotels, offices, apartment houses etc.

Type of Ceiling

Ordinary timber joist floors, flat-slab floors, ribbed floors, etc., provide flat ceilings, whereas concrete floors, supported by beams and girders, etc., require suspended ceilings, if flat ceilings are to be obtained. Different types of ceilings are provided for different floor systems. Plastered ceilings are generally provided to the underside of ribbed slabs or steel beams. Monolithic concrete ceiling surfaces are often finished by painting directly rather than on plaster.

Wearing Surface

The type of wearing surface is an important factor in selecting the type of floor system, or vice-versa. The following combinations of wearing surface and base or sub-floor are considered suitable from economic point of view.

(a) Wood flooring as wearing surface is provided for light wood joist and heavy timber floors.

(b) The flooring of linoleum, cork, concrete, magnesite, asphalt tile, plastic tile, cork carpet, rubber, ceramic tile, etc., is provided as wearing surface for any type of floor system with concrete top surface.

(c) The flooring of ceramic tile, marble, slate, terrazzo, etc. as wearing surface also requires a concrete foundation and hence a concrete base.

5.4.4 Construction Details of Upper Floors

Construction details of some of these upper floor has been described here, for rest, you may refer any of the standard text.

Timber Floors

Timber floors, though quite light in weight, have poor fire resistance and sound insulation properties. They are quite costly, except at those locations where local timber is cheaply available. It is also highly vulnerable to termite attack. Timber floors are basically of three types; single joist, double joist and triple or framed joists timber floor.

Single joist timber floor is the simplest type used for residential buildings, where spans are short or moderate (about 4 m) and loads are comparatively lighter. The floor consists of wooden joists spaced 30 to 40 cm apart and supported on end walls, over which timber planking or boarding is fixed. The width of joists are kept 5 to 8 cm wide. The depth of the joists is determined from the thumb rule :

$$\text{Depth (cm)} = (4 \times \text{Span in m}) + 5 \text{ cm}$$

The joists are supported on wall plates 10 × 7 cm to 12 × 7 cm in size, at the end walls. A space of about 5 cm is kept at the ends for air circulation. When the span exceeds 2.5 m, it becomes essential to strengthen the timber joists by providing herring bone strutting 5 × 3 cm to 5 × 5 cm as shown in Figure 5.4. End wedges are provided between the wall and joists. The end of the joists are nailed, cogged or notched to the wall plates. If the joists of adjacent room run in the same direction, they may be overlapped and nailed to each other. Planking consists of wooden boards of 4 cm thick and 10 to 15 cm width, which are fixed to the bridging joists.

Figure 5.4 : Single Joists Timber Flooring

Double joists timber flooring is stronger, and is used for spans between 4 to 8 metres. The bridging joists are supported on intermediate walls in the form of highly concentrated loads. This feature of double joist timber flooring is a disadvantage of this type of flooring. Also, the overall depth of the flooring is increased. Because of intermediate supports, the bridging joists are of smaller sections, and are spaced at 30 cm centres. The spacing of binders is kept 2 to 3.5 m, and they rest on stone or wooden bearing templates which are not less than 0.75 to 2.5 m in length. In order to reduce the overall depth of the floor, bridging joists are cogged to the binders, with depth of sinking equal to $1/3^{rd}$ depth of bridging girders and bearing not less than 2.5 cm. Alternatively, the ends of the bridging girders are cut, and they are jointed with the help of fillers provided along the two sides of the binder.

Triple or framed joist type of floor is suitable for spans greater than 7.50 m, in which intermediate supports, known as *girders*, are provided for the binders. Sometimes, the wooden girders may be replaced by rolled steel joists.

Steel Joist and Stone or Precast Concrete Slab Floors

Stones are available in many parts of the country and hence, this flooring is used for economy and ease in construction. This type of floor is quite common in locations where flag-stones or stone-slabs are readily available in spans of 1 to 3 metres and widths 30 to 60 cm. Where stone slabs are not available, precast concrete slabs can be used. The slabs are placed at the lower flange of rolled steel joists (RSJ), specially where plain ceiling is required, though in this case the bearing to the slabs is small (Figure 5.5(b)) Otherwise, the slabs can be supported on the upper flange of RSJ by inserting wide stone bedding plate, called *suboti* between the flange and the slab (Figure 5.5(c)). When the slabs are placed on the lower flange, of joists, the space between the top of the slab and top of RSJ is filled with lime concrete or light weight cement concrete, after encasing the steel joists completely in cement concrete so that they do not get rusted. On the top of it, regular flooring is laid.

Figure 5.5 : Stone Slab Floor Supported on Steel Joists

The spacing of the rolled steel joist depends upon the length of available stone slabs. The joists have the clear span equal to the width of the room (Figure 5.5(a)). The bearing of joists on the wall should at least be equal to depth of the joist, but in no case less than half the width of the wall. It is better if bearing is kept, just equal to the width of the wall so that eccentric load of the wall is eliminated. A bed plate is provided below each end of the joist, to suitably distribute the load to the wall. Stone slabs are available in lengths of 1 to 3 m, if the width of the room is slightly less than this value, stone slabs can be directly supported on the walls, without using steel joists. Such a construction is quite cheap.

Jack Arch Floors

These floors are formed by constructing brick or concrete arches, called 'Jack arches' on the lower flanges of mild steel joists. The joists are spaced 1 to 1.5 m centre to centre, and are supported at their ends either on the walls or on longitudinal girders. The jack arches are usually given a small rise of 1/12th of the arch span. The minimum depth of concrete at the crown is kept equal to 15 cm. Since the super-imposed load is being borne by arch action, tension is developed on the supporting walls, specially at the end span. Due to this, steel tie rods are provided at the end span, at suitable spacing, usually 1.8 to 2.4 m c/c. The tie rods are 2 to 2.5 cm diameter, and are properly anchored into the wall. The end arch is supported on wall by either providing rolled steel joist into the wall or simply fixing an angle iron or mild steel in the wall. The bottom of the floor is not plane, which is the only disadvantage of this floor.

Brick Jack Arch Flooring

The construction on jack requires centering of 30 to 40 mm thick segmental piece of timber, with chord length equal to the span of the arch and conforming to the soffit. Then centering board is cut slightly at the ends and is made to rest on the lower flange of RSJ, with the curved surface upwards. Figure 5.6 shows the details of brick jack arch flooring. Alternatively, a bend iron strap is attached to its ends to form a hook through which the

(a) Jack Arch

(b) Centering Details

Figure 5.6 : Brick Jack Arch Floor

centering board is suspended from RJS, as shown in the Figure. After the centering is ready, bricks are laid on edge from both the joists. The end bricks are cut suitably to fit firmly with the joists. Only well-burnt bricks are used for the construction, and they are saturated with water, before use. Joists are encased in cement mortar, so as to prevent their rusting from lime mortar. The bricks are laid in such a way that necessary bond is developed between different rings or layers of bricks. In the first ring, the bricks are laid in lengths of 20 cm and 10 cm alternatively, to secure good bond between this ring and the next ring along the length of arch (perpendicular to the span). The key brick at the crown is laid in rich mortar, and is pushed as tight as possible. After the first ring is complete, the centering board is advanced or pushed 20 cm further, by light blows of hammer, to construct the second ring. The second and successive rings are constructed using 20 cm long bricks. The last ring, however, is constructed with alternate bricks of half and full lengths. The entire brickwork is watered or cured for 15 days. The top flooring is then provided on a bedding of lime concrete or light weight cement concrete put on spandril.

Cement Concrete Jack Arch Flooring

The construction of concrete jack arches is relatively simple. The centering consists of a 3 mm thick mild steel plate, bent to the shape of arch soffit, and having pair of holes at ends, spaced at 75 cm c/c longitudinally. The centering plate is supported on the lower flange of joists through a pair of 12 mm diameter rods, each having an eye hook at its end. Each rod passes through the end eye of the other, and their total length is adjusted to the span of the arch. Figure 5.7 shows a cement concrete jack arch flooring in which the arches are made of 1 : 2 : 4 cement concrete, supported on the lower flanges of MS joists. The ends of the rods pass through symmetrical holes of the centering plate (Figure 5.7(b)), and finally rest on the lower flange of RSJ, thus providing the support to the MS plate, as shown in Figure 5.7(a).

(a) Cement Concrete Jack Arch Flooring

(c) Centering Details

Figure 5.7 : Cement Concrete Jack Arch Flooring

In order to check the deflection of the centering plate, a wooden packing block is tightly inserted between the MS plate and the rods. When the centering is ready, cement concrete of 1 : 2 : 4 mix is laid on the top of the MS plate, to the required depth and is properly compacted either manually or with the help of a vibrator. The flooring is then completed with the desired type of flooring material. The entire work is then well watered for 10 days, for efficient curing. After that, the centering is removed by first removing the wooden packing and then hammering the eyes of the rods toward each other. The underside of the arches can be plastered to give good appearance.

Reinforced Brick Flooring

Reinforced brickwork is a typical type of construction in which the compressive strength of bricks is utilised to bear the compressive stresses and steel bars are used to bear the tensile stresses in a slab. In other words, the usual cement concrete is replaced by the bricks. However, since the size of a brick is limited, continuity in the slab is obtained by filling the joints between the bricks by cement mortar. The reinforcing bars are embedded in the gap between the bricks, which is filled with cement mortar. Such type of construction is quite suitable and cheap for small span floor slabs carrying comparatively lighter loads. Figure 5.8(a) shows typical sections of reinforced brick slab.

The depth of reinforced brick slab is governed by the thickness of the bricks available. Modular bricks are 10 cm thick (nominal). Hence thickness of slab may be kept as 10 cm or 20 cm. If 15 cm thickness is required from design point of view, 5 cm thick tiles are used on the 10 cm thick bricks to make a total thickness of 15 cm (Figure 5.8(b)). The joint between the two layers of tile and brick is filled with cement mortar. Before use, the bricks should be thoroughly soaked in water. The reinforcing bars put in the joints should not come in contact with bricks.

When two layers of bricks are used, vertical joints in the bricks should be broken (staggered) so that slab does not shear along the joint. The bricks near the edge should rest half on the bearing wall so that vertical joint above the edge of the wall is avoided. First class bricks should be used for such a work. Cement mortar used to fill the joints etc. should be of 1 : 3 ratio, with proper water-cement ratio to make the mortar workable. The width of the joint between adjacent bricks is generally kept equal to 2 cm. The compressive strength of reinforced brickwork is sometimes increased by providing wider gap (say about 4 cm) between the bricks, and providing 2.5 to 5 cm thick layer of cement concrete on the top of the bricks, as shown in Figure 5.8(c).

Figure 5.8 : Reinforced Brick Slab

Reinforced Cement Concrete (RCC) Floors

RCC floors are becoming very popular in the construction of modern buildings because of the inherent advantages of this type of construction. Concrete, though strong in compression, is weak in tension. However, it is suitably reinforced with the help of mild steel bars which take the entire bending tension. Due to this, the overall thickness of RCC floors is comparatively small, thereby reducing the self weight of floor itself. RCC floors are also comparatively fire proof and damp proof. The method of construction is also easy except that centering is required. These floors can also be used on large spans and, therefore, more suitable for big size rooms, halls etc.

In RCC flooring, the RCC slab bends downwards, causing tension at the bottom fibres. Due to this mild steel bars reinforcement is placed at the bottom of the slab, keeping a minimum clear cover of 15 mm. Half these bars are bent up near ends to take up negative bending moment caused due to partial fixidity at the ends. This main reinforcement is placed in the direction of the span of the slab, which is equal to the width of the room, specially when the length of the room is more than 1.5 times the width of the room. Such a slab is known as one way reinforced slab. Nominal reinforcement (known as temperature/distribution reinforcement) is placed in the perpendicular direction. Hooks are placed at the end of each plain bar, though these are not required in ribbed bars (tor-reinforcement). The bearing of the slab in the wall should neither be less than its thickness, nor less than half the width of the wall. Figure 5.9(a) shows one way reinforced slab. Such slabs are quite suitable and economical for spans up to 5 m.

Figure 5.9 : Reinforced Concrete Slabs

The slab is cast on timber or steel shuttering. After erecting the centering, properly bent reinforcement is placed in position. Distance pieces of stone or concrete are placed between the reinforcement and the shuttering plate so that proper cover is maintained. Cement concrete of appropriate mix (usually 1 : 2 : 4) is then poured and well-compacted. The slab is then properly cured. Shuttering is removed only when the concrete has fully set.

When the length of the room is less than 1.5 times the width of the room, the slab spans bends in both the directions. It is essential to provide reinforcement in both the directions. Such a slab is known as a two-way reinforced slab, such as the one shown in Figure 5.9(b). At the corner, suitable mesh reinforcement is provided at the top and bottom, to prevent their lifting.

When the width of room becomes more, the span of slab increases, and simple RCC slab becomes uneconomical. In that case, the floor structure consists of RCC beams and slabs cast monolithically. The beams, known as T-beams, act as intermediate supports to the slab which is continuous over these beams. When the size of the room (i.e. hall) is very large, these floor beams are supported on longitudinal beams which, in turn, are either supported on RCC columns or end walls. Figure 5.10 shows details of beam slab flooring.

Figure 5.10 : Beam-Slab Flooring

5.5 PRE-CAST CONCRETE FLOORS

With the modern developments in construction technology, precast beam-slab units are now available with the help of which the floors can be constructed easily and expeditiously, without the aid of any formwork. These precast units are available in about 25 cm width, various depths, and various spans, and can be supported either on walls or on rolled steel joists. The sides of each unit are provided with grooves to form connecting joggles for adjacent units. The joints are grouted with cement mortar, using concrete guns. Such floors are light weight, sound proof, fire proof, and economical.

SAQ 2

List the various types of upper floors and materials used in their construction. Also discuss the various factors you would consider in their choice or selection.

SAQ 3

Explain the procedure of constructing the following types of flooring :

(a) Reinforced brick slab floor

(b) Jack arch floor of bricks

(c) Reinforced cement concrete floor

(d) Double joist timber floor.

5.6 SUMMARY

In this unit, we have studied about floors and their types, material used for their construction, and important factors to be considered prior to selection of a particular type of floor. We have also covered construction details of some of the important types of ground and upper floors. Learner may refer any of the standard text to cover construction details of all other types of floors.

After studying different types of flooring, we shall study the details of doors and windows forming openings in the walls for specific purposes in the next unit.

5.7 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section 'Further Reading' given at the end to get the answer of the SAQs.

CONSTRUCTION TECHNOLOGY-I

Construction technology can be considered to be the technology required to be applied during construction of a civil engineering structure. In the course of study for Diploma in Civil Engineering, buildings are considered in detail. In the courses of construction technology, you will be exposed to various details pertaining to building construction. Keeping in view the vastness and importance of buildings, the knowledge base is divided into two courses. In the present course, you will be introduced to some basic and essential aspects of building construction. Other important and advanced issues will be covered in Construction Technology-II course.

The course comprises six units.

Unit 1 is on foundations. Construction of any building starts with the construction of foundation which is designed to transfer all the horizontal, vertical, impact and shock loads borne by any building or any of its component or services, safely to a hard and strong strata below the ground level. The study deals with the objective of providing the foundation, investigations required for site and soil to determine its characteristics and load carrying capacity, and then choosing the appropriate type of foundation.

Unit 2 entitled “Superstructure” presents a brief description of main structural components of buildings, e.g. frames and walls. Different types of walls are described like load bearing, partition, and cavity walls etc. Walls are constructed of masonry which could be bricks, stones, concrete blocks or reinforced brickwork etc. The unit also describes in brief the materials and techniques employed in masonry construction along with the workmanship and quality systems used.

Unit 3 deals with potential dangers faced by a building and its users in the form of termites, damp and water ingress. These three hazards affect the living quality of building users, and reduce the durability of structure and its various components. In this unit, you will study the details of various precautions and measures, which must be undertaken to save the building from these hazards and make it termite, damp and water proof.

Unit 4 is on lintels, arches and scaffolding. Lintels and arches are important structural components provided in superstructures to facilitate horizontal openings provided for doors, windows, ventilators and other purposes. You will study different types of lintel and arch employed in normal buildings, their classifications, materials used and techniques of construction. The unit also describes different types of temporary structures called scaffoldings, used to facilitate the above constructions and other provisions like plastering, painting, plumbing etc.

Unit 5 entitled “floorings” deals with floors which are essential component of a building provided to give a level surface to support and for the functional use to building users. You will study different types of floor and floor finishes, their classifications, factors affecting the selection of a particular floor types, and their construction details.

Unit 6 entitled “Doors and Windows” describes the various means of providing access into the building to its users, and to allow proper ventilation and natural lighting in all its interiors. Different types of door, window and ventilator, their materials and techniques of production are described in detail.

With the study of this course and its assimilation you will have the basic knowledge of building construction and technology employed.

In this course, you will find that each unit provides a number of Self Assessment Questions (SAQs) to help you to self-monitor the progress made in the process of knowledge acquisition. If you go through the text attentively and then attempt the SAQs independently, you will develop a confidence in meeting the functional needs of your selected profession.

We wish you all a grand success in all your educational endeavours.