UNIT 13
FLOORINGS

Structure

13.0 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.

13.1OBJECTIVES

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.

13.2 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)
- Floor Covering (or Paving, or Flooring)

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.

13.3 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.

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.

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

13.3.2 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. Terrazzo 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 flooring or mosaic asphalt flooring

13.3.3 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 color 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 are 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, especially 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.

13.3.4 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 especially suited to ware-houses, stores, godowns etc. Brick flooring is commonly used in alluvial places like UP, Punjab etc. Well-burnt bricks of good color 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).

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 13.3 shows details of concrete flooring.

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 colors), 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. Color 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 at least 85% of the finished surface show exposed marble chips. The surface is then floated and troweled, 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 scrubbed and cleaned. Cement grout of cream like consistency, of the same color, 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 115 carborundum stones of fine grade (No. 120). The surface is scrubbed 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 scrubbed 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 pozzolana material, is spread and is left to dry for about 4 hours. Thereafter, small pieces of broken tiles or marble pieces of different colors 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 *terrazzo* 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 color 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 indifferent 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 shearing compressed in molds 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.

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.

13.4.1 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.

13.4.2 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

13.4.3 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 labor, 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, labor 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 analyzed 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 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 is 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, 1st 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 multistoried 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.

13.4.4 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 is 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 is 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.

Double joists timber flooring is stronger, and is used for spans between 4 to 8 meters. 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 centers. 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 forthe 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.

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 13.5(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 center to center, and are supported at their ends either on the walls or on longitudinal girders. The jack arches are usually given a small rise of $1/12^{th}$ 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, especially 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

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 13.7(b)), and finally rest on the lower flange of RSJ, thus providing the support to the MS plate, as shown in Figure 13.7(a).

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 utilized 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 13.8(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 13.8(c).

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 fibers. 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, especially 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.

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 13.9 (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 13.10 shows details of beam slab flooring.

13.5 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.

13.6 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.