Building Materials

1·1. Characteristics of Good Building Stones

(U.P.S.C. Engg. Services Exam., 1979, 81. 82. 84. 86, 87)

Good building stones must possess the following qualities.

1. **Appearance.** The stones should be of uniform colour and for architectural point of view, these should match with the surroundings. Lighter colours are preferred to darker ones as the latter are less durable. The property of the appearance of stones is extremely important for the face work of buildings. The good stones should also be able to receive good polish.

2. **Strength.** The stones used in the construction of buildings are generally subjected to compressive stress. These should therefore, be able to withstand the compression without getting crushed due to the load of the structure. Though all stones used for the construction of ordinary buildings, possess workable strength in compression but the strength of stones used for the construction of heavy structures should always be tested before use. Closed grained and uniform textured stones are generally good in strength.

3. **Structure.** A good stone when broken in a direction other than that of cleavage (if any) should not give a dull appearance. These should be either closed grained or crystalline and should show uniformity of texture. These should also be free from cavities and cracks. If the stones are obtained from sedimentary rocks, their stratification should not be visible to naked eye.

4. **Hardness.** A good stone when used in floors, pavements and aprons of bridges, should be able to resist the abrasive forces caused due to wear and friction. Hardness of stones can be tested by Mohr's scale of hardness in the laboratory whereas in field, it can be tested by knife scratching. Hard stones do not show any mark of scratching.

5. **Toughness.** Good stones should also be tough enough to withstand stresses developed due to vibrations of machineries and moving loads over them. Stones used in the construction of roads should be hard as well as tough.

6. **Heaviness.** The stones used for the construction of dams, weirs, barrages, docks and harbours, should be of heavier varieties. In case of dams and roof coverings, lighter varieties of stones are preferred to. The specfic gravity of good building stones should lie between 2·4 to 2·8.

7. **Durability.** Good stones should resist the action of the atmosphere such as wind, rain and temperature. The effect of atmospheric

conditions on stones is generally known as *weathering*. Durability of stones largely depends upon their chemical composition and physical structure. A durable stone should have a compact and crystalline structure, free from pores.

8. **Porosity and absorption.** A good stone should not be porous. It should not absorb water when immersed. Porous stones are unsuitable for the construction work as rain water falling on their exposed surface get driven in the pores of stones by the prevailing winds. The rain water generally becomes acidic due to atmospheric acidic gases and this acidic water reacts with the constituents of stones causing them to crumble. In higher region water in the pores when freezes, disintegrates the stones because of increased volume after freezing. Porous stones should be used in the construction of structures with care and at places which are not exposed to frost, rain or moisture.

9. **Resistance to fire.** Stones when exposed to fire should be able to resist temperature. To ensure this, stones should be free from minerals which are likely to decompose on heating such as calcium carbonate and iron oxide. Stones should not be composed of minerals having different coefficients of thermal expansion. Quartz expands at low temperature and argillaceous variety of stones resist high temperature.

10. **Dressing.** The art of converting a natural stone into a definite shape, is known as *dressing*. Stones should therefore possess good dressing properties for carving and structural work in building constructions. Marbel is a good example. It may be noted that a stone possessing good dressing properties on the other hand, is weak in strength and durability, and also its hardness is low.

11. **Seasoning.** A good stone should be free from quarry sap. To ensure this, the stones after quarrying and dressing should be left for a period of 6 to 12 months for proper seasoning, before using in the construction work.

1·2. Suitability of Stones for Various Types of Construction

The types of stones used for various types of construction are :

	Type of Structure	*Type of Stone*
1.	Piers, bridge abutments, light houses, and wiers.	Good quality granite, Good or stratified granite.
2.	Road pavements and railway ballast.	Inferior quality of granite and Gneiss.
3.	Road metalling, paving.	Basalt and trap.
4.	Cement concrete.	—do—
5.	Ornamental work in building.	Red and yellow types of basalt and trap.
6.	Roof covering and flooring	Slate
7.	Damp proofing and sills of windows.	Slate
8.	Partitions in urinals and bath rooms.	Slate
9.	Ornamental buildings, monuments, statues and carved work.	Marble
10.	Building construction	Laterite
11.	Interior decoration in superior buildings.	Serpentine

1·3. Operations involved in the manufacture of bricks

(*U.P.S.C. Engg. Services Exam., 1985*)

Brick making involves the following operations.

1. **Preparation of clay.** Good brick earth, a mixture of pure clay and sand along with a small quantity of finely divided lime is first dug out, broken up, watered and kneaded well under feet till it becomes a homogeneous mass. The tempered earth is then covered up with mat pieces and allowed to dry gradually till it is just soft-enough for moulding. For manufacturing superior bricks, the clay is generally prepared by pug mills.

2. **Moulding.** The well prepared clay is moulded in rectangular steel or wood moulds without top and bottom, their longer sides project a few centimetres to act as handles. Bricks are usually moulded on a block of wood having a projection 6 mm deep and same length and breadth as the inside dimensions of the mould. Moulding of bricks done on the stock board, is called *table moulding*.

3. **Drying.** The moulded bricks are then allowed to dry so that these are sufficiently hard to be handled. When the bricks become sufficiently hard, these are stacked. Eight or ten layers of bricks on edge with intervals of about one metre between them, are generally stacked.

4. **Burning.** Well dried bricks are burnt in clamps or kilns to attain desired crushing strength and also to impart red or yellowish colour.

1·4. Classification and Characteristics of Bricks as per Indian Standard Institution.

(*U.P.S.C. Engg. Services Exam., 1981, 82*)

According to IS : 1077—1971, the classification and characteristics of bricks, are as tabulated on page 6.

1·5. Tests for the acceptance of bricks for building construction.

(*U.P.S.C. Engg. Services Exam., 1984, 87*)

Before accepting the bricks for building construction, the

Classification of Bricks

Sl. No.	Type of Bricks (classification)	Properties	Where Used
1.	First class bricks	These bricks are well burnt, having smooth and even surface, with perfect rectangular shape and uniform reddish colour. When struck with other brick, these give a metallic ringing sound. These should not leave any mark when scratched by finger nail. These should not absorb water more than 20% of its weight when immersed in cold water for 24 hours. When broken into two pieces these should show a uniform compact structure. These show slight efflorescence.	These are used for good structures such as outer walls and facing work when no plastering is done. These are also used in floors and reinforced brick slabs. Such bricks should be laid in rich mortar.
2.	Second class bricks.	These are not perfectly rectangular in shape and are having rough surface, but are hard, slightly over-burnt and uniform in colour. These give ringing sound when struck with each other. Water absorption should not be more than 22% by weight, when immersed in water for 24 hours. These show slight efflorescence.	These are used for internal walls, not exposed to atmosphere. These are used in facing work, which should be plastered. These cannot be used for R.B. work. Such bricks may be laid in mud or lime mortar.
3.	Third class or Pila bricks.	These bricks are not burnt properly in the kilns and may be slightly under/over-burnt, hence these are soft and can be easily broken. These are light red in colour, with yellowish tinge. On striking, these do not give a ringing sound. These should not absorb more than 25% of water by weight when placed in cold water for 24 hours. Efflorescence in these bricks is moderate.	These are used for inferior construction works, or at places where there is less rainfall or presence of dampness.
4.	Jhama or over-burnt bricks.	Due to excess fusion and temperature, bricks get over-burnt, loose their shape and get twisted. These bricks are dark bluish in colour.	These bricks are not used in building construction work. In the form of broken pieces, these may be used as road metal, also in foundations and floors as soling material.

following tests are generally performed.

1. Dimensions and tolerances test
2. Compressive strength test
3. Water absorption test.
4. Efflorescence test.

1·5·1. Dimensions and tolerances test. This test is performed to know the accuracy of the dimensions of the bricks.

Procedure. Proceed as under :

(1) Take twenty bricks out of the given samples.

(2) Remove loose particles of clay and small projections from the bricks.

(3) Arrange them on a level surface in contact with each other and in a straight line.

(4) Measure the overall length of the bricks having size $19 \times 9 \times 9$ cm laid by means of a steel tape.

(5) The dimensions of 20 bricks should be within the following limits.

Class	*Length*	*Width*	*Height*
Class A	368 to 392 cm	174 to 186	174 to 186 cm
Class B	350 to 410 cm	165 to 195 cm	165 to 195 cm.

1·5·2. Compressive Strength test. This test is performed to determine the crushing strength of bricks.

Procedure. Proceed as under :

(1) Take five bricks out of the sample at random.

(2) Immerse the bricks in water at room temperature for 24 hours.

(3) Take out the bricks from the water and wipe off surplus water from their surfaces.

(4) Fill the frogs and all voids in the bed and face with cement morter 1 : 1 (1 cement : 1 clean sand)

(5) Store the bricks under damp gunny bags for 24 hours and there-after immerse them in water for 72 hours.

(6) Take out the bricks from water, wipe off dry. Place the bricks with flat surfaces horizontal and mortar filled frog face upward between two or three thin ply sheets and centre them between the plates of compression testing machine.

(7) Apply the load at a uniform rate of 140 kg/cm² per minute till the brick fails.

(8) Take the average value of the compressive strengths of the five bricks.

(9) The compressive strength of a common brick should be 50 kg/cm².

1·5·3. Water absorption test. This test is performed to determine water absorption of the bricks. If the water absorption capacity of a brick is more, its strength will be comparatively low.

Procedure. Proceed as under :

(1) Select five bricks at random out of the given sample.

(2) Dry them in a ventilated oven at 105° to 110°C till they attain practically constant weight.

(3) Remove the bricks from the oven and cool them to room temperature.

(4) Weigh the bricks in a balance. Let it be W_1 kg.

(5) Immerse the five bricks in water completely at 27°±2C for 24 hours.

(6) Remove one brick from water and wipe off its surfaces with a damp cloth.

(7) Weigh the brick within three minutes after its removal from water. Let its weight be W_2 kg.

(8) Water absorption capacity

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

(9) Take the average value of the water absorption capacities of the five bricks.

(10) For 1st Class bricks, the water absorption capacity should not be more than 20% by weight.

1·5·4. Efflorescence test. This test is performed to know the presence of any alkaline matter in the bricks.

Procedure. Proceed as under :

(1) Take five bricks at random from the given sample.

(2) Place each brick on end in a dish containing distilled water, ensuring depth immersion at least 2·5 cm.

(3) Keep the dish in a ventilated room (Temp. 20° to 30° C) till the whole of distilled water in the dish evaporates.

(4) Again pour 2·5 cm depth of distilled water in the dish and keep it till the whole of water gets evaporated.

(5) Now, examine the bricks for efflorescene as detailed below :

Observation	*Result*
(*i*) No perceptible deposit	Nil-efflorescene
(*ii*) 10% area covered with thin deposit of salts	Slight-efflorescene
(*iii*) 50% area covered with deposit of salts without any powdering or flaking surface.	Moderate-efflorescene
(*iv*) 50% area covered with deposit of salts accompanied by flaking of surface.	Heavy-efflorescene
(*v*) Heavy deposits of salts accompanied by flaking of the surface.	Serious-efflorescene

1·6. Terra-Cotta. *(U.P.S.C. Engg. Services Exam., 1985)*

Terra-cotta which is baked clay or baked earth is a superior veriety of clay products and is usually moulded in the same manner as bricks. It is made from a mixture of fine clay (60%), crushed pottery (20%), white sand (14%) and powdered glass (6%), with a quantity of desired colouring substance.

For making a porous and sand proof terra-cotta, either sawdust or ground cork may be mixed with clay before moulding. Organic particles burn away during the burning of the moulded and dried terra-cotta and thus leaving behind small pores. Terra-cotta is used for architectural and ornamental parts of superior buildings as a substitute for stones. It is used as sound proof material and its hollow blocks prevent dampness in the structure.

1·7. Glazing of white ware products.
(U.P.S.C. Engg. Services Exam., 1985)

Surfaces of white ware products are generally glazed to improve their appearance and also to protect them from the action of atmosphere, sewage and strong chemical agents.

For providing transparent glazing, self glazing is the most important method. In this method a solution of sodium chlorides is thrown in the kiln when the product is well burnt at a temperature 1200° to 1300°C. Due to high temperature, the sodium chloride evaporates and combines with silica of soil to make soda silicate. Soda silicate again combines with alumina, lime or iron of the clay to form a thin transparent layer. Vapours of volatilised salt get into every pore of the product and thus make it impermeable.

1·8. Characteristics of Good Timber
(U.P.S.C. Engg. Services Exam., 80, 81, 84, 88)

Good timber should possess the following qualities.

1. **Hardness.** It should be hard.

2. **Strength.** It should be able to resist heavy loads in structural members.

3. **Toughness.** It should be tough enough to resist shocks due to vibrations. It should not break in bending and should resist splitting. Timbers with narrow annual rings, are generally the strongest.

4. **Elasticity.** It should be elastic so as to regain its original shape after removal of loads. This property is very important for the timber used in sports goods.

5. **Durability.** It should be able to resist the attacks of fungi and worms and also atmospheric effects for a longer duration.

6. **Defects.** It should be from the heart of a sound tree and be free from sap, dead knots, shakes and other similar defects.

7. **Fibres and Structure.** It should have straight and closed fibres and compact medullary rays. It should give a clear ringing sound when struck. Dull heavy sound is an indication of internal decay. Its annual rings should be uniform in shape and colour.

8. **Appearance and colour.** Freshly cut surface should give sweet smell and present shining surface. It should have preferably dark colour, as light coloured timbers are generally weak in strength.

9. **Shape and weight.** It should retain its shape during the process of seasoning. Heavy timbers are always stronger than light weight timbers.

10. **Workability.** It should be well seasoned and easily workable. Teeth of saw should not get clogged during the process of sawing. It should provide smoothened surface easily.

1·9. Structure of a Timber (Fig. 1·1)

The cross-section of the trunk of a timber tree may be distinctly divided into four parts.

1. **Pith, heart or medulla.** Inner most part or core of the stem, which consists entirely of cellular tissues, is called *pith.*

2. **Medullary sheath.** The portion consisting of vascular tissues and which encloses the pith, is called *medullary sheath.* Medullary rays are vertical layers of cellular tissues and spider-like radial lines originating from the pith to the bark. Medullary rays bind the annual rings to one another. Large and distinct radial lines are called silver grains or flowers.

3. **Annual rings.** These consist of cellular tissues and woody fibres arranged in distinct concentric circles round the pith. Annual rings are generally formed in every year, due to the deposition of sap below dark. Number of annual rings indicates the age of a tree in a tropical climate. Sap wood consists of outer annual rings. Heart wood consists of inner annual rings round the pith.

4. **Bark or Cortex.** It consists of cells of wood fibre and is the outermost cover or skin of the stem.

1. Bark
2. Cambium
3. Annual rings
4. Pith or heart
5. Medullary shea
6. Heart wood or duramen
7. Sap wood
8. Medullary rays.

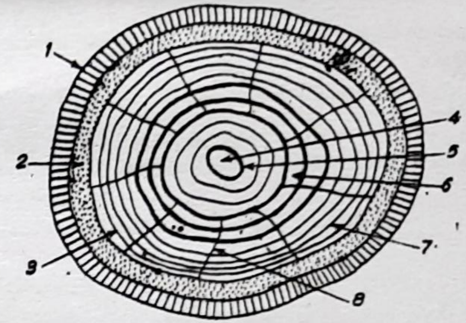

Fig. 1·1. Structure of timber.

1·10. Characteristic differences of sap wood and heart wood

(U.P.S.C. Engg. Sesvices Exam, 1985)

The main characteristic differences of sap wood and heart wood are as under :

1. **Sap wood.** (*i*) Sap wood is younger in age and lighter in colour.
   (*ii*) It is easily attacked by insects.
   (*iii*) Its annual rings are far apart.
   (*iv*) It possesses less strength.

2. **Heart wood.** (*i*) Heart wood is older in age and darker in colour.
   (*ii*) It is hard core of the stem and is not attacked by insects.
   (*iii*) Its annual rings are nearer to each other.
   (*iv*) It possesses more strength.

1·11. Characteristic differences of hard wood and soft wood

(U.P.S.C. Engg. Services, Exam., 1985)

The main characteristic differences of hard wood and soft wood, are as tabulated below.

Characteristic	*Soft wood*	*Hard wood*
1. Annual rings	Clearly visible and far apart.	Less distinct and nearer to each other
2. Medullary rays	Indisitinct	Distinct
3. Colour	Lighter	Darker
4. Heart wood and sap wood	Can not be distinguished	Can be distinguished
5. Fibres	Straight and possess high tensile strength	Strength of fibres same in all directions.
6. Sawing	Easy	Difficult
7. Resinuneous material	Exists in pores	Does not exist
8. Examples	Chir, and other coniferous trees	Teak, mahagony, Sal, etc.

1·12. Preservation of Timber

A properly seasoned timber is most durable. If it is not seasoned properly, it is likely to be attacked by insects *i.e.* white ants, dry and wet rots. Timber should be used either fully dried in well ventilated positions or well immersed in water. In water the timber does not decay though it becomes soft and weak. In case timber is not seasoned before it is used, it should be preserved by the application of preservatives. In masonry construction, the timber should not be used in direct contact with lime mortar.

Preservation of timber may be done by one of the fallowing methods :

1. **Charring.** Lower ends of the timber posts before embedding in ground, are generally charred to a depth of 1·5 cm and quenched in water, to prevent attack from dry rots and worms.

2. **Tarring.** Embedded portion of timber fence posts, ends of door and window frames, bettons and beams built in walls are usually tarred.

3. **Painting.** Painting the surface of timber members, protects it from moisture and thus prolongs it life. Paints possess excellent preservative properties and protect the timber against the attack of white ants. Paints are available in varieties of shade with different trade marks.

4. **Creosoting.** Creosote oil is a dark brown thick liquid. By applying creosotes to timber, chances of attacks of white ants and rots are reduced considerably. In this method well seasoned timber dried for 24 hours, is kept in air tight chamber and air is exhausted. Creosote is then pumped in at a pressure of 9 kg/cm^2 at a temperature of 50°C till it is fully saturated with oil. Creosoting is done for railway sleepers, piles and transmission poles.

5. **Wolmen Salt.** A timber treated with wolmen salt which consists of creosote and sodium flouride dissolved in water, is extremely fire resistant and free from fungi attacks. Zinc chloride, sodium flouride, magnesium silco-fluoride and copper sulphate when applied to timber also help it from the attacks of fungi. On drying, such timbers are suitable for painting.

6. **Ascu.** A timber treated with Ascu powder developed by F.R.I. (Forest Research Institute) Dehra Dun is immune to the attacks of white ants and may be painted, varnished and polished.

7. **Fire proofing of timber.** A timber to some extent, may be made fire proof by soaking it in ammonium sulphate, ammonium chloride, ammonia phosphate, sodium arsenate or zinc chloride.

1·13. Defects in Timber

The following are the most common defects in timber.

1. **Heart Shakes** [Fig. 1·2 (*a*)]. These are splits occurring in the centre of the tree and running from the pith towards the sapwood in the direction of medullary rays. In some timbers, these splits

are hardly visible and in some timbers these are quite permanent. Heart shakes are caused due to shrinkage of the interior parts due to age. A heart shake straight across the trunk, is not a serious defect.

2. **Star Shakes** [Fig. 1·2 (*b*)]. These are splits which radiate either from the centre of timber or from the bark, running in the planes of medullary rays. Star shakes are mostly confined to sapwood and are caused due to severe frost and scorching heat of the sun.

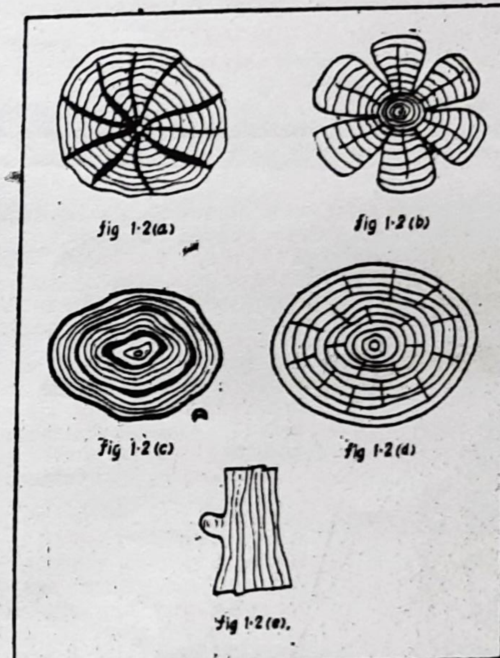

Fig. 1·2. Defects in timber.

3 **Cup Shakes** [Fig. 1·2 (*c*)]. These are curved splits which separate the whole or part of one annual ring from another. These are caused due to unequal growth of timber.

4. **Radial Shakes** [Fig. 1·2 (*d*)]. These are similar to star shakes, and occur in felled timbers when exposed to sun during seasoning, Radial shakes are generally irregular, fine and numerous. Many splits appear to start a few centimetres within the bark, run a short distance towards the centre, then following the course of an annual ring, approach the centre radially.

5. **Rind-galls** [Fig. 1·2 (*e*)]. These are typical enlarged swellings caused generally by the growth of layers over the wounds left after the branches have been cut off.

6. **Rupture.** These are caused due to fibres having been injured by crushing.

7. **Twisted Fibres.** The twisting of fibres is caused due to the action of prevalent wind twisting the young tree constantly in one direction.

8. **Wind cracks.** These are shakes or splits on the sides of a bark of timber due to the shrinkage of the exterior surface exposed to atmospheric influences.

9. **Knots.** These are the roots of small branches of the tree. These break the continuity of fibres. These are not much harmful if small, hard and rounds. Timber with large dead (loose) knots of many smaller ones, should be rejected as these do not provide specified strength.

10. **Dead wood.** It is deficient in strength and weight and is the result of trees being felled after maturity.

1·14. Seasoning of Timber and its Necessity

(*U.P.S.C. Engg. Services Exam., 1984, 86*)

Definition. The process of drying timber or removing moisture or sap from a freshly felled tree, is called *seasoning of timber*.

A well seasoned timber may contain about 0 to 12 per cent moisture which is necessary for proper retention of the shape and size of the articles manufactured from the timber. On the other hand if a timber is not properly seasoned before use, it is liable to shrink warp, crack, rot and decay. This is why properly seasoned timber need only be used for high class timber work.

Necessity of seasoning a timber. Seasoning of timber is done for the following purposes :

1. To reduce the weight of the timber for acheiving economy in its transportation from the place of felling to the place of manufacturing the articles.

2. To minimise the tendency to shrink, split and warp in the manufactured wood work.

3. To increase the strength and durability of the timber and also to make the timber electrically resistant.

4. To improve the wood working qualities in timber for gluing, painting and polishing the surfaces of finished articles.

5. To enable to provid proper preservation treatment of the timber.

6. To make the timber free from the danger of being attacked by insects, fungus, etc.

7. To acheive good characteristics in timber.

1·15. Methods of Seasoning Timber

(*U.P.S.C. Engg. Services Exam. 1979 86*)

According to IS : 1141—1973, the following are the methods of seasoning the timber :

1. Natural or air seasoning.

2. Artificial or kiln seasoning.

1. **Natural or air seasoning.** A felled log if left on the ground for long is likely to be attacked by insects and fungi. It should therefore be converted by sawing into desired dimensions and stacked on well drained place in the shade. The main principle of seasoning is to remove the moisture from the timber. While stacking, it should be ensured that there is free circulation of fresh air around each piece. (Fig. 1·3),

For natural air seasoning a suitable concrete foundation, a few centimetres above the ground is provided to stack the logs under shade. Care should be taken not to expose the freshly converted timber stacked for seasoning to sun or to severe winds. To avoid the tendency of splitting of hard wood during seasoning, cleats are fixed and nailed to their ends.

This method of seasoning is the best as it gives very strong and durable timber but it takes longer time. It generally takes more than six months for timber to season in moderate climates. Timber seasoned by natural seasoning method, generally contains 18% of moisture,

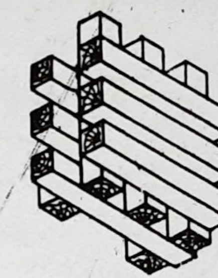

Fig. 1·3. Air seasoning.

2. **Artificial or kiln seasoning** Seasoning of timber by this method is done in a masonry chamer equipped with an arrangement for heating, controlling humidity and circulating the air in the kiln. Steam is generally used for heating and humidifying the air in the chamber. The timber in the chamber is stacked as for natural seasoning In the begining, the seasoning is started at a comparatively lower temperature and high humidity. Initially, moisture content in the timber is more and hence at higher temperature, the wood shrinks and cracks develop. As the moisture from the timber decreases, the temperature of the chamber is increased. At times, the sample pieces of wood are taken out of the seasoning chamber and their percentage of moisture content is checked. As the timber dries, at the end of seasoning, the temperature of the air inside the chamber

is raised fairly high and humidity is reduced. The seasoned timber is allowed to cool in the chamber within 20°C of the outside temperature before removal. Seasoning by this method generally takes four to five days under normal conditions.

Kiln seasoning is a quick method of seasoning timber to the desired moisture contents.

Advantages and disavantages of kiln seasoning are tabulated hereunder :

Advantages	*Disadvantages*
1. Perfect control of drying	1. It requires skilled supervison
2. Economy of time.	2. Expensive in cost.
3. Moisture content may be reduced to desired level.	3. Due to carelessness, the wood develops surface cracks, warping and splitting.
4. Unlikely to be attacked by fungi and insects.	
5. Wood receives paints well.	

1·16. Constituent Parts of Paint and Their Functions
(*U.P.S.C. Civil Services Exam., 1982*)

The constituent parts of paints are the following :

1.. **Base.** 2. **Vehicle.** 3. **Colouring Pigments.** 4. **Thinner.** 5. **Drier.** 6. **Adulterant.**

1. **Base.** It is very finely grounded metallic oxide. It acts as a body of paint. Because of film of base, the paint becomes hard and resistive to weathering friction. The most commonly used bases in paints are :

White lead, Lead sulphate, Sublimed lead, Red lead, Zinc oxide, and Titanium oxide.

2. **Vehicle.** The material used in paints to help it to spread the base over the surface is called *vehicle*. It acts as a binder between base and pigment and causes it to adhere to the surface to be painted. Vehicle is mixed with the bases to form a paste. Most commonly used vehicle, is Linseed Oil of the following four types *i.e.*

(*i*) Raw Linseed Oil.

(*ii*) Refined Linseed Oil.

(*iii*) Pale boiled Linseed Oil.

(*iv*) Wouble boiled Linseed Oil.

3. **Colouring Pigments.** The materials added to the paints to obtain desired final colour, is called *colouring pigments*. These are used to obtain the final colour of the paint different from that of the base.

Depending upon the final colour of paints, the colouring pigments may be used. Such as lamp blank, bone black, graphite, Indian red, chrome yellow, etc.

4. **Thinner.** The material used in paints to reduce its consistency, is called *thinner*. It enables the paint to be spread over the surface to be painted with the brush and to penetrate into the surface. Most commonly used thinner is turpentine oil which dries rapidly and helps to dry paint soon.

Naptha and spirit are also sometimes used as thinner.

5. **Drier.** The material used in paints, to accelerate the action of drying is called *drier*. Paints need be dried soon to avoid the risk to catch dust and dirt. Most commonly used drier is *Litharge* whose use in finishing coat should be avoided, otherwise colour of paint may change due to change in atmospheric conditions.

6. **Adulterants.** The material which is used to reduce the cost of paint and also to reduce the weight and to increase its durability, is called *Adulterant*. Barium sulphate is widely used as adulterant because of its cheapness and its property not to react with paint. Calcium Carbonate, Magnesium Silicate and Silica are also used as adulterants.

1·17. Manufacture of Cement by Wet Process
(*U.P.S.C. Civil Services Examination, 1982*)

For the manufacture of cement, following ingredients are required.

1. Lime stone 2. Clay 3. Coal 4. Gypsum.

Process. The cement is prepared by mixing 75% of limestone and 25% clay. Hard lime stone is powdered in a crusher. Clay is thoroughly mixed with water in a wash mill. Powdered lime stone and clay solution are then mixed and ground in a wet grinding mill to form a slurry having a moisture 32 to 40%. The slurry is stirred in a collecting basin, and is tested for its chemical composition as described below.

(*i*) Slurry to be taken in tube and mix HCl to it.

(*ii*) The mixture is heated till precipitation occurs.

(*iii*) The mixture is cooled to obtain a jelly like material.

If the jelly so formed is hard, it indicates that the proportion of the mix is not correct. Either clay or limestone is then added as required in correcting basin itself. This test is very important and must be carried out by an expert, because if proportion is not correct, the properties of resulting cement will adversely change.

From the correcting basin, slurry is dumped to a storage basin, where it is constantly stirred by mechanical process. From storage basin, the slurry is pumped to upper chamber of the rotary kiln, regularly.

Rotary kiln consists of an inclined cylinder supported on masonry chamber 15 metres apart. Its length varies from 90 to 120 metres and diameter varies from 3 to 3·5 metres. The diameter of the cylinder in burning zone, is comparatively large than that of other zones.

Slurry is admitted from the upper chamber of the kiln, to the higher portion of the cylinder which makes one revolution per minute and pulverised coal is entered from other end. When the slurry reaches the buring zone (temp. 1500 to 1600°C), CO_2 gas is evolved after heating and the moisture evaporates. Hot chamber is then cooled by blowing in cool air in the outlet pipe. To delay the setting time of the resulting cement, gypsum (3 to 4%) is added at this stage.

Klinker is then ground in ball mill and tube mill in which balls grind the klinkers to a very fine powder, called *cement*.

2

Building Construction

2·1. Foundation

The lowest part of a structure which transmits the weight of the structure together with live loads, seismic and wind pressure to the material on which the structure rests, ensuring its safe bearing capacity, is called *foundation*. To increase the stability of the structure, foundations are generally placed below the ground level.

2·2. Functions of Foundations

Following are the main functions of foundations :

1. To transmit and distribute the total load of the structure to a larger area of underlying support.
2. To prevent differential settlement of the structure.
3. To provide stability to the structure.

2·3. Types of Foundations

The following are the main types of foundations :

1. **Spread foundations.** The total load of the structure transmitted to the base of the structure is spread over a large area by spread foundations. The width of the wall is constructed thicker at the base in a stepped fashion.

2. **Pile foundations.** A pile is a long vertical load transferring member composed of either ti nber, steel or concrete. In pile foundations, a number of piles are driven in the base of the structure. The piles are of two types *i.e.*, (*i*) Friction pile ; (*ii*) End bearing pile.

(*i*) **Friction pile.** The pile which supports the structure load due to friction between the pile and surrounding soil, is known as *friction pile*.

(*ii*) **End bearing pile.** The pile whose lower end rests on a hard rock, is called *end bearing pile*.

The tops of various piles are connected by reinforced beams, to distribute the load uniformely to the under lying soil.

Pile foundations are specially suitable in water logged areas or in compressible soil or on steep slopes.

3. **Pier foundations.** In this type of foundation, hollow vertical shafts are sunk up to the hard bed and hollow portions are then filled up with inert material such as sand or lean concrete

Pier foundations are specially suitable for heavy structure such as flyovers in sandy soil or soft soil overlying hard bed at reasonable depth.

2.4. Types of Spread Foundations (Figs. 2.1, 2.2)

1. **Wall footings.** Wall footings may be either simple or stepped. Simple footings are provided for walls which carry light loads whereas stepped footings are provided for walls which carry heavy loads.

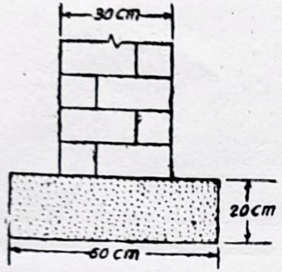

Fig. 2.1. Simple wall footing.

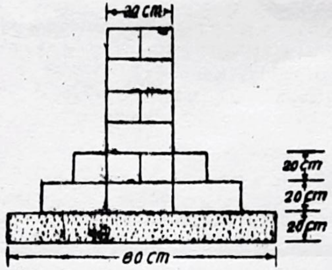

Fig. 2.2. Stepped wall footing.

The concrete for the footings generally consists of 1 : 3 : 6 or 1 : 4 : 8 concrete mix.

(*i*) **Minimum depth of footings.**

According to Rankine's formula, $D=\frac{P}{w}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$

[where P=safe bearing capacity of soil in kg/m^2

w=unit weight of soil in kg/m^3

ϕ=angle of repose of soil in degrees

D=minimum depth of footing in metres.

(*ii*) **Width of footing.** Width of footing may be computed by dividing the total load (including live load and wind load) by the allowable bearing capacity of the soil.

If B=width of footing in metres

W=load per metre run in kg

P=safe bearing capacity of the soil in kg/m^2

then $B=\frac{W}{P}$.

(*iii*) **Depth of concrete bed.** Though concrete bed may fail due to crushing, shearing and bending, its depth is generally designed for the maximum bending moment from the formula,

$$d=0{\cdot}775\,x$$

where x is an offset of the concrete bed in centimetres.

2 **Isolated footings.** (Fig. 2.3 and 2.4) Isolated foundations are generally provided under isolated columns to transfer the load of the structure to the soil bed. For brick masonry columns

isolated footings are generally provided steps on all the four sides in regular layers with 5 cm offsets. For columns which carry heavy loads, reinforcement is provided in both the directions with 15 cm offsets on the sides.

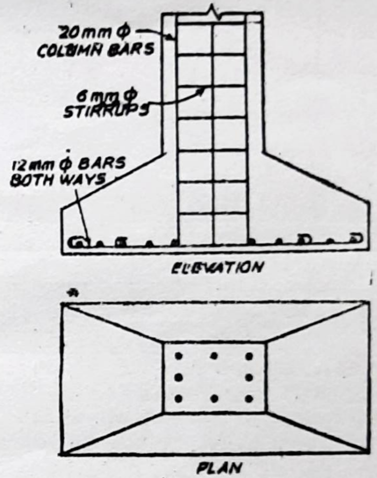

Fig. 2.3. Isolated footing.

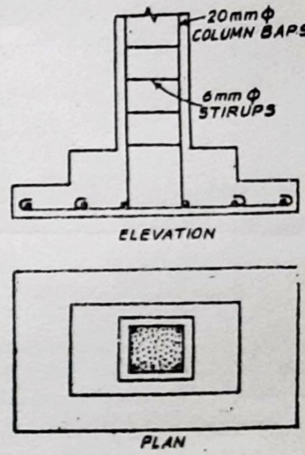

Fig. 2.4. Isolated footing.

3. **Combined footing.** The common footing which is constructed for two or more columns, is called a *combined footing*. The

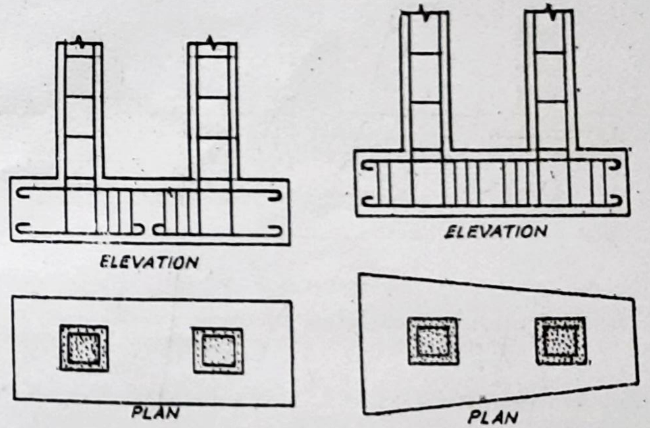

Fig. 2.5. Combined footings.

shape of a combined footing is so proportioned that the centre of gravity of the resultant area, coincides with the centre of gravity of the column loads.

The general shapes of a combined footing is either rectangular or trapezoidal as shown (Fig. 2·5).

4. **Cantilever footings.** (Fig. 2·6). A cantilever footing consists of an eccentric footing for the exterior column and a concentric footing for the interior column and both the footings are connected by a strap or a cantilever beam. The load from the exterior column is balanced by the interior column load acting about a fulcrum. The connected strap beam checks unequal settlement of the external column.

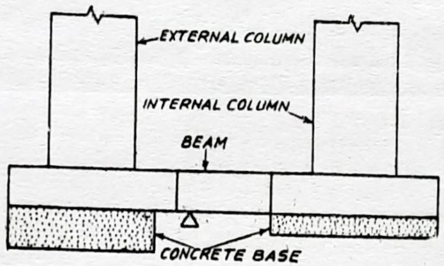

Fig. 2·6. Cantilever footing.

5. **Inverted arc footing** (Fig. 2·7). The footing which consists of inverted arches between the piers, is called an *inverted arch footing*. The rise of the inverted arches is about one-fifth to one tenth of the span. The loads transmitted to the soil through inverted arch footings, are distributed over a larger area and hence, inverted arch footings are suitable in soft soils for bridges, reservoirs, tanks, etc.

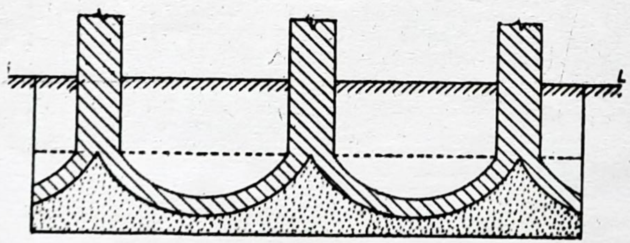

Fig. 2·7. An inverted arc footing.

6. **Grillage foundations** (Fig. 2·8). The foundation which consists of one or two tiers of wooden or rolled steel sections with space filled up with concrete, is known as *grillage foundation*. These

foundations are used to transfer the heavy structural loads from the columns to soils having low bearing capacity. Grillage foundation is generally constructed with rolled steel joists placed in two tiers. Top tiers is placed at right angles to the bottom tier. The distance between the flanges is kept 1·5 to 2 times the width of the flange or

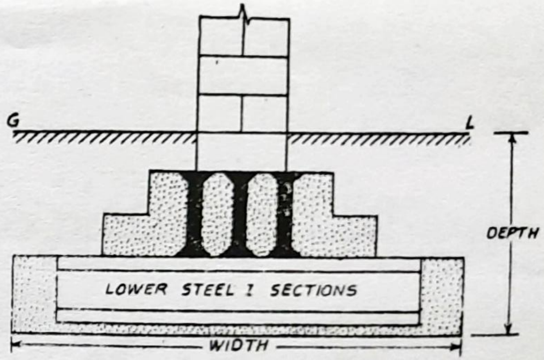

Fig. 2·8. A Grillage foundation.

30 cm whichever is less. The tiers of R.S.J. are completely embedded in rich concrete to protect the steel from corrosion.

7. **Raft foundations** (Fig. 2·9). The foundation which consists of a thick R.C.C. slab covering the whole area in the form of a mat is known as *raft foundation*. Raft foundation is provided if large isolated footings are required to support the structure. If the required area of footing exceeds half the total area of the structure, then a raft foundation is generally used.

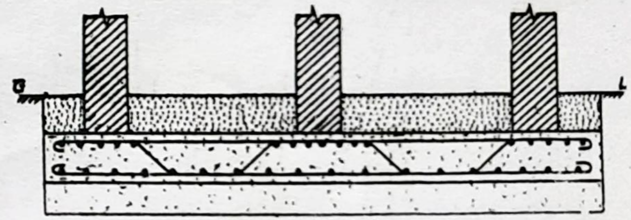

Fig. 2·9. Raft foundation.

Raft foundations are used for increasing the area of foundation, to cover soft or loose pockets in the soil and to neutralise the hydrostatic uplift pressure.

8. **Stepped foundations** (Fig. 2·10). The foundation having its bed in the form of steps of concrete, is known as *stepped founda-*

tion. Such foundations are provided when natural ground has steep inclination, to avoid deep excavations.

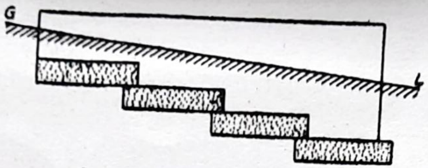

Fig. 2·10. Stepped foundation.

2·5. Pile Foundations

Piles used in the foundations may be classified as under :

1. **Bearing piles.** Bearing piles transfer the superimposed load through them to hard stratas at considerable depths.

2. **Friction piles.** Friction piles transfer the superimposed load through them to the soft soil by the frictional forces developed between the ground soil and the surface of the pile.

3. **Battered piles.** Battered piles are used to resist the inclined forces.

4. **Sheet piles.** Sheet piles consist of thin members of steel sheet or timber.

5. **Under-ream piles.** Under reams piles are provided bulbs known as *under-reams*, to increase the bearing capacity of the soil considerably.

2·6. Load Bearing Piles

1. **Cast iron piles.** Cast iron piles are hollow tubes of cast iron having inner diameter 20 to 40 cm and wall thickness 20 to 30 mm. These are generally 4 metres in length and for longer lengths these are joined by suitable device. Cast iron being a brittle material, these piles are provided with helical screws at the lower end and the whole assembly is rotated to drive the pile inside the soil. Piles with helical screws are generally known as *screw piles*.

Cast iron piles are suitable for shallow foundations and are suitably employed for the foundations of marine structures, light weight bridges and buoys anchors.

2. **Cement concrete piles.** These are of the following types.

(A) **Cast-in-situ piles.** These piles are cast with cement concrete at the place where these have to carry superimposed load. For casting the pile, a hole is driven by excavating with an auger or driving a casing. The hole is then filled up with cement concrete. As these piles are generally driven vertically, no reinforcement is needed. If the casing is left in position, the pile is known as *cased*

cast in-situ concrete pile and if the case is withdrawn, the pile is known as *uncased cast-in-situ concrete pile*.

The uncased cast-in-situ concrete piles are of the following types :

(*i*) **Simplex pile** (Fig. 2·11). A hollow cylindrical steel casing with one pointed iron shoe attached to its bottom is driven into the ground to the desired depth. Concrete is then pured into the casing pipe for a depth of about one metre and compacted. The casing pipe is lifted up for a distance of one metre. In this way entire length of the hole is filled up with compacted concrete which acts as a pile.

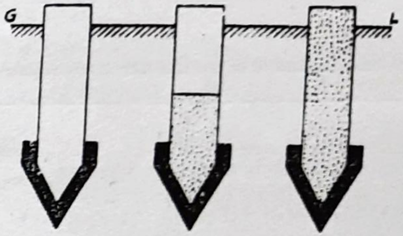

Fig. 2·11. Simplex piles.

(*ii*) **Frankie pile** (Fig. 2·12). It consists of an enlarged base and corrugated stem. Initially 60 cm to 90 cm bottom portion of the casing pipe is filled with concrete and compacted by dropping a hammer to provide a solid plug at the end. The casing is then driven in by hammering the concrete plug till it reaches the desired depth. Now the casing is lifted to a small distance and the concrete is forced by the hammer blows. Successive layers of concrete are then poured and compacted, and simultaneously the casing is lifted.

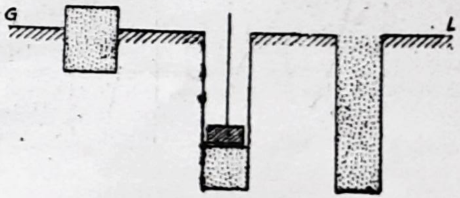

Fig. 2·12. Franki pile.

(*iii*) **Pedestal Pile.** A concrete pile with a pedestal at the bottom end is known as *pedestal pile*. The pile may consist of plain cement concrete or reinforced cement concrete.

(*iv*) **Pressure pile.** A pile which is made by pouring cement concrete inside a casing pipe in layers of 30 cm, and each layer being compacted by compressed air, is called a *pressure pile*. The casing is gradually lifted. Such piles can resist shocks and vibrations to a greater extent.

(*v*) **Vibro pile.** A hollow steel tube with a cast iron shoe at its bottom, is driven into the ground to the desired depth. The casing is filled with fresh cement concrete. The casing is then removed by pulling upward and hammering downward. Such piles are cast with a rapid speed and generally these consist of dense and uniform concrete.

(*vi*) **Under-reamed pile.** (*U.P.S.C. Civil Services Exam. 1983*). In soils which experience alternate swelling and shrinkage due to changes in its moisture content, under reamed piles are used for transferring heavy loads. Under-reams are provided at distances 1·5 ϕ apart, where ϕ is the diameter of the bulb. The number of under reams, is decided according to the load, the foundations are supposed to carry.

(B) **Cased cast-in-situ concrete piles.** The cast-in-situ concrete piles in which casing is left in the ground, are of the following types :

(*a*) **Raymond pile.** In this type of piles, a corrugated thin steel sheet tapered shell is driven into the ground with a collapsible steel mandrel inside it to a desired depth. The reinforcement cage is inserted into the sheet and cement concrete is poured into it. These piles are suitable for lengths varying from 6 to 15 metres.

(*b*) **Monutube pile.** In this type of piles, tapered steel shell without any mandrel is used as casing. It is driven into the ground to desired depth. Reinforcement case is inserted into the shell and cement concrete is then poured into it.

(*c*) **Mac-Arthur pile.** In such piles heavy steel casing is driven into the ground with a core inside it to a desired depth. The core is then pulled out and a corrugated steel shell is inserted. Finally cement concrete is poured and outer casing is withdrawan.

(*c*) **Button bottom pile.** In such piles, a button shaped bottom is used at the lower end of the steel casing which is driven into ground to a desired depth. A corrugated steel shell is lowered into the steel casing. The steel casing is removed and cement concrete is poured into the shell.

Advantages and disadvantages of cast-in-situ concrete piles

The following are the advantages of cast-in-situ concrete piles.

(*i*) Less wastage of the material.

(*ii*) Saving in reinforcement because extra reinforcement required to withstand stresses of handling and driving is minimised.

(*iii*) Less curing time is required.

(*iv*) More strength in the absence of hammer blows.

(*v*) Saving in transportation of pre-cast piles.

The following are few disadvantages of cast-in-situ concrete piles.

(*i*) No proper compaction.

(*ii*) No proper alignment of reinforcement.

(*iii*) Not suitable for areas flooded with water.

(*iv*) Loss of water from cement concrete in dry soil, which affects water cement ratio.

(*v*) The unreinforced piles generally break due to lateral movement of the soil.

3. **Sand piles.** In this type of piles, holes are driven into ground to desired depth and sand is filled in the holes. Such piles improve the bearing capacity of the soil. If instead of sand, gravels are used, the piles are called *gravel piles*.

4. **Timber piles.** In this type of piles, piles of hard and strong timber pile carries a cast iron shoe and upper end is provided with a steel plate to receive hammering stress. If a number of timber piles are used, their tops are provided with a concrete cap known as *pile cap*.

5. **Steel piles.** Steel piles may be either H-piles, box piles or circular tube piles.

(*a*) **H-piles.** These piles are suitably used in hard soil by driving to desired depth by hammering. These are generally used in retaining walls.

(*b*) **Box piles.** These piles are generally rectangular, square or octagonal in shape. These consist of deep beams which offer adequate frictional resistance and end resistance.

(*c*) **Circular tube piles.** These piles consist of circular steel tubes driven into ground to desired depth. From the open ended pile, soil is removed and cement concrete is poured.

6. **Wrought iron piles.** These piles are generally solid and circular, having diameters ranging from 80 to 200 mm. Their normal length is between 4 to 6 metres. These are especially suitable as shafts for screw piles.

7. **Composite piles.** These piles are a combination of a bored pile and a driven pile or of driven piles of two different materials. A combination of timber and cement concrete, is generally preferred to.

2·7. Coffer Dams

The temporary enclosures built in round the working area in water for the purpose of keeping water off from the area and to provide dry conditions for construction works, are called *coffer dams*.

Coffer dams are of the following types :

1. Cantilever sheet pile.
2. Braced coffer dam.
3. Embankment protected coffer dam.
4. Double wall coffer dam.
5. Cellular coffer dam.

2·8. Causes of Foundation Failure

A foundation may fail due to following causes.

1. Unequal settlement of the sub-soil.
2. Unequal settlement of the structure.
3. Lateral horizontal earth pressure on the structure.
4. Shrinkage of sub-soil strata due to temperature variation.
5. Escaping of soil from the sub-soil of foundation.
6. Penetration of the roots of trees below foundation.
7. Siesmic effects on the foundation.

2·9. Brick Masonry

The arrangement of laying bricks and bonding them with mortar properly to form a unified mass which can transmit the super-imposed load safely to the foundation, is known as *brick masonry*.

2·10. Technical Terms used in Brick Masonry

1. **Course.** The layer of bricks laid on the same bed, is known as a *course*. The thickness of the course is equal to actual thickness of the brick plus the thickness of one mortar joint.

2. **Frog.** The depression provided in the face of the brick to form a key with mortar and to reduce the weight of the brick, is called '*frog*'.

3. **Bed.** The bottom surface of the brick when it is laid flat, is known as *bed*.

4. **Stretcher.** The side surface of the brick when laid longitudinally and visible in elevation. is called as *stretcher*.

5. **Header.** The end surface of the brick when laid transversely and visible in elevation, is called as *header*.

6. **Arrises.** The edges formed by the intersection of plane surfaces of a brick, are called *arrises*.

7. **Perpends.** The vertical joints between bricks either in longitudinal or cross-sections, are called *perpends*.

8. **Bats or Closers.** The bricks cut to reduced sizes, are called *bats* or *closers*.

9. **Types of closers.** The closers are of two types :

(*i*) **Queen closer.** The half brick cut across the width of the standard brick, is called *queen closer*.

(*ii*) **King closer.** The brick whose one portion extending from half width to half length is removed, is called *king closer*.

10. **The quoin.** The angle of a wall surface at the corner, is called *quoin*.

11. **Facing.** The exposed surface of a wall or structure, is called *facing*.

12. **Backing.** The internal surface of a wall or structure, is called *backing*.

13. **Hearting.** The portion of the wall or the structure in between backing and facing, is called *hearting* or *filling*.

14. **Lap.** The horizontal distance between two perpends in two successive courses, is called *lap*.

15. **Bull nose.** The bricks having one or two edges rounded, are called *single bull nose* and *double bull nose*.

2·11. Nominal and Actual Sizes of Modular Bricks

The normal size : $20 \times 10 \times 10$ cm.

The actual size : $20 \times 9 \times 9$ cm.

2·12. Bonds

The arrangements of bricks in order to tie them together in a mass of brick work, is called *bonding*.

Following are the types of bonds :

1. Stretcher bond	7. Facing bond.
2. Header bond.	8. Dutch bond.
3. English bond	9. Raking bond.
4. Single flemish bond	10. Zig-zag bond.
5. Double flemish bond.	11. English cross bond.
6. Garden wall bond.	12. Brick on edge bond.

1. **Stretcher bond.** All the bricks when laid with their lengths in the longitudinal direction of the wall, are said to be laid in stretcher bond. It is suitable for half brick walls only.

2. **Header bond.** All the bricks when laid with their headers towards he face of the wall, are said to be laid in header bond. It is suitable for one brick wall only.

3. **English bond.** [*U.P.S.C. Engg. Services Exam., 1983*]. The bond which contains alternate courses of stretchers and headers,

is called *English bond*. In English bonds, a queen closer is laid after first header courses to stagger the vertical joints of successive joints. (Fig. 2·13).

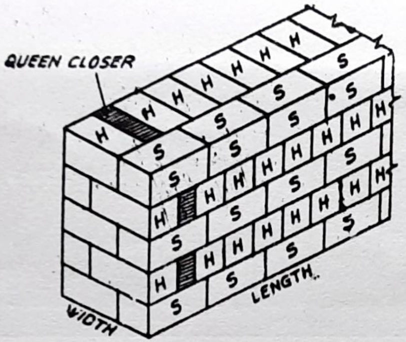

Fig. 2·13. An English bond.

4. **Single Flemish bond.** [*U.P.S.C. Engg. Services Exam. 1980*]. The bond in which headers and stretchers are laid alternately in the same course, is called *Single Flemish bond* (Fig. 2·14).

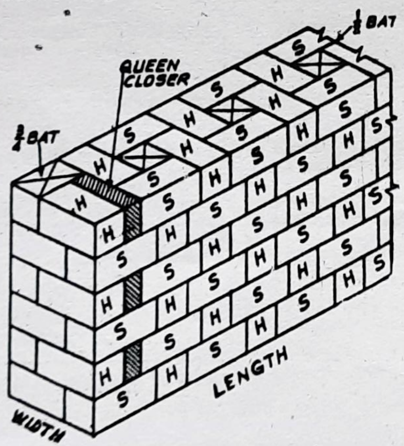

Fig. 2·14. A Flemish bond.

In this type of bond, the facing of the wall consists of flemish bond and the filling as well as backing consists of English bond in each course.

5. **Double flemish bond.** In this type of bonds, both the facing and backing of the structure consists of flemish bonds, and the filling consists of either stretchers or headers.

6. **Garden wall bond.** These bonds may be either English garden wall bond or flemish garden wall bond.

(*i*) **English garden wall bond.** It consists of one course of headers to three to five courses of stretchers. For staggering the vertical joints, a queen closer is laid next to the queen header of header course and the middle course of stretchers, is started with a header.

(*ii*) **Flemish garden wall bond.** It consists of courses in which one header and three to five stretchers are laid. ¾ bats are laid in every alternate course next to quoin header.

2·12·1. Comparison between English bond and Flemish bond

(*U.P.S.C. Engg. Services Exam. 1979*)
(*U.P.S.C. Civil Services Exam., 1983*)

English bond	*Flemish bond*
1. Headers and stretchers are laid in alternate courses.	1. Headers and stretchers are laid alternately in each course.
2. Strongest of the types of bonds.	2. Comparatively less strong for walls more than 30 cm thick.
3. Provides rough appearance.	3. Provides good appearance.
4. Absence of vertical joints in the structure.	4. Partly continuous vertical joints appear in the structure.
5. Special attention is not required for this bond.	5. Special attention is required for bond.
6. Progress of work is more.	6. Progress of work is less.
7. Costly, no brick bats are used.	7. Economical, as brick bats are used.

2·13. Bricks Copings

These are provided on the tops of garden walls, boundary walls and parapets to protect them from rain water.

2·14. Brick Corbels

The projecting bricks from a wall constructed to support beams, trusses, etc. are called *brick corbels*. The maximum projection of the corbel, is limited to thickness of the wall.

2·15. Thickness of the Brick Walls

If T = thickness of the wall
L = length of the wall
W = weight on the wall
P = allowable compressive strength

then
$$T = \frac{W}{P \times L}.$$

2·16. Stone Masonry

The art of building structures in stones, is called *stone masonry*.

2·17. Comparison between stone masonry and brick masonry

Stone Masonry	*Brick Masonry*
1. Stones are natural material obtained from quarries.	1. Brick are artificial material manufactured by moulding and bringing in the form of rectangular blocks.
2. Dressing of stones is required.	2. Dressing of bricks is not required.
3. Bonding is not good but strength is more.	3. Bonding is good but strength is less.
4. Skilled labour and care required.	4. Less skilled labour and care required.
5. Difficulty in lifting and laying.	5. Convenient in lifting and laying.
6. For desired strength rich and more quantity of mortar needed.	6. For desired strength comparatively weak and less quantity of mortar needed.
7. Mortar joints are irregular and continuous.	7. Mortar joints are seldom continuous.
8. Plastering of stone masonry is not done.	8. Plastering of brick masonry is done on inside faces.
9. Possesses less resistance to fire and good appearance.	9. Possesses more resistance to fire and simple appearance.
10. Thickness to be more than 35 cm.	10. Thickness can be even up to 10 cm.
11. Costly and difficult to construct ornamental works.	11. Cheap and easy to construct ornamental works.

2·18. Technical terms used in Stone Masonry

The following terms are generally used in stone masonry :

1. **Natural bed of a stone.** The original surface occupied by a stone during its formation, is called *natural bed.* Stones are placed in a structure so that super-imposed load acts perpendicular to the natural bed of stones.

2. **Bedding plane.** The plane along which a stone can be separated easily, is called *bedding plane.* Stones are laid in a structure so that load acts perpendicular to their bedding plane.

3. **String course.** The course of stone masonry provided at floor level and roof level projecting horizontally outside the wall of a building, is called *string course.*

4. **Cornice.** The course of a masonry provided at ceiling level of the roof projecting outside the surface of the wall of a building, is called *cornice.* It is provided to throw rain water away from the wall and also to add architectural appearance.

5. **Throating.** A small groove cut on the under side of a projecting chhajja, cornice, coping, to discharge rain water without trickling to walls, is called *throating.*

6. **Reveals.** The exposed vertical surfaces perpendicular to window or door frame, are called *reveals.*

7. **Drip stone.** A projecting dressed stone having its under surface throated, is called *drip stone.*

2·19. Classification of Stone Masonry

(U.P.S.C. Civil Services Exam., 1983)

Stone masonry may be either rubble masonry or ashlar masonry.

1. **Rubble masonry** (Fig. 2·15). The stone masonry in which roughly dressed or undressed stones are laid in a suitable mortar, is called *rubble masonry.*

Fig. 2·15. Rubble masonry

Rubble masonry may further be divided into three main types.

(*i*) Uncoursed random rubble masonry.

(*ii*) Coursed random rubble masonry.

(*iii*) Dry rubble masonry.

(*i*) **Uncoursed random rubble masonry.** The masonry in which stone blocks not properly dressed are used as obtained from the quarry, is called *uncoursed random rubble masonry.* In this type, vertical joints are not constructed in plumb.

(*ii*) **Coursed random rubble masonry.** The masonry in which 5 to 20 cm sized stones of equal height are used in every course, is called *coursed random rubble masonry.*

(*iii*) **Dry rubble masonry.** The structure made with stones laid in different courses, without any mortar, is called *dry rubble masonry.*

2. **Ashlar masonry** (Fig. 2·16). The stone masonry in which properly cut in uniform size and dressed with fine finish, stones are laid with a mortar of uniform thickness, is called *ashlar masonry.*

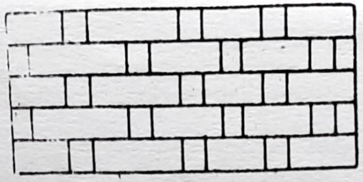

Fig. 2·16. Ashlar Masonry.

Ashlar masonry is further classified as under :

(*i*) **Ashlar fine.** In this type of stone masonry, the stone blocks are finely chisel dressed and their faces are made perfectly true in shape. In construction proper bonds are provided and joints are kept less than 3 mm. The face stones are normally laid as headers and stretchers in alternate courses. The height of stones used in masonry should never be less than their breadth.

(*ii*) **Ashlar rock or quarry faced.** In this type of stone masonry, the exposed faces of facing stones, are used as obtained from the quarry. If the stone projection is more than 8 cm, it is hammered to provide a rough suface.

(*iii*) **Ashlar chamferred.** It is similar to the quarry faced masonry with a difference that edges round the exposed faces of each stone, are levelled at an angle of 45° for a depth of 2·5 cm.

(*iv*) **Ashlar facing.** In this type, the exposed face is constructed with stone masonry and backing is constructed in brick masonry, rubble masonry or concrete masonry. The backing and facing are constructed simultaneously. The composite contruction reduces the expenditure to a great extent.

2·20. General Principle for Supervision Stone Masonry
(*U.P.S.C. Engg. Services Exam., 1979*).

The following are the general principle of supervision :

The stone used in masonry should be durable and strong.

2. All stones should be well watered before laying, to avoid absorption of moisture from mortar.

3. All stones should be properly dressed.

4. The stones should be laid on their natural beds so that pressure acts normal to beds.

5. The different sized stones should be placed so that continuity of vertical joints, is broken in the structure.

6. The stones from opposite faces should make proper bond with each other.

7. **The height of stones should never be greater than their minimum horizontal dimension.**

8. **Small stone chips should never be used in bed joints.**

9. **Quoins should be laid as stretcher and header in alternate courses.**

10. Large flat stones used as bed plates should be provided under the ends of beams, girders etc.

11. The hearting of the masonry should be properly packed with stone chips to avoid hollows.

12. **The upper surface of old structure must be cleaned before placing the mortar.**

13. **The joint on the surface should be raked at least 2·5 cm deep and pointed with rich cement mortar.**

14. **Double scaffolding should be used.**

15. After masonry is laid, it should be cured for a **period of 2 to 3 weeks.**

2·21. Purpose of Plastering
(*U.P.S.C, Civil Services Exam., 1983*)

The plastering of buildings is provided for the following purposes :

1. To provide an even, smooth and durable finished surface.
2. To improve the apperance of building.
3. To protect the surface from the effects of weathering agents *i.e.* water, temperature, etc.
4. To conceal the defective workmanship and inferior **quality of materials** used in construction.
5. To provide a smooth base for colour washing, painting or distempering.
6. To protect the internal surfaces against dust, dirt and vermin nuissance.
7. To protect porous materials and faulty joints.
8. To provide satisfactory insulation against sand and fire.

2·22. Types of Plaster

Following are the types of plaster.

1. **Lime plaster.** Lime mortar contains equal volume of lime and sand. The mixture is finely ground in a mortar mill.

2. **Cement plaster.** Cement mortar contains one part of cement and 3 to 4 parts of clean, course and angular sand. The mixture is thoroughly mixed in dry conditions on a water-tight platform.

3. **Stucco plaster.** Stucco plaster is a decorative type of plaster with elegant finish like that of marble.

4. **Water proof plaster.** It consists of one part of cement two parts of sand and pulverised alum 12 kg per cubic metre of sand. Water containing 75 gm of soft soap per litre is used for preparing the mortar.

5. **Plaster on lath.** Lath is used as a base to the plaster work.

2·23 Defect in Plastering

Defects in plastering are :

(1) Cracks, (2) Efflorescence,
(3) Blistering, (4) Falling off.

2·24. Pointing

The process of finishing the mortar joints with separate material in brick or stone masonry, is called *pointing*. It is provided to protect the joints from rain water, and also to impart better appearance to the exposed surface.

The following are the types of pointings.

1. Flush pointing.
2. Recessed pointing.
3. Struck pointing.
4. Tuck pointing.
5. Keyed, grooved or rubbed pointing.
6. V-groove pointing.
7. Weathered pointing.
8. Beaded pointing.

2·25. Cavity Walls

The wall consisting of two separate walls with a hollow space in between, is called a *cavity wall.*

The advantages of cavity walls are :

1. Prevention of dampness.

2. Heat insulation.
3. Sound insulation.
4. Economy in construction cost.

2·26. Causes of Dampness

The main causes of dampness in the buildings are :

1. Orientation of the building.
2. Rain water.
3. Exposed tops of the walls.
4. Rise of ground water table.
5. Condensation.
6. Poor drainage.
7. Bad work manship.

2·27. Materials used for Damp-proofing

The following materials are generally used for damp-proofing.

1. **Bitumen** 2. **Mastic asphalt**
3. **Bituminous felt** 4. **Mortar**
5. **Cement concrete** 6. **Stones**
7. **Metal sheets.**

2·28. Arches

The various parts of an arch are shown in Fig. 2·17.

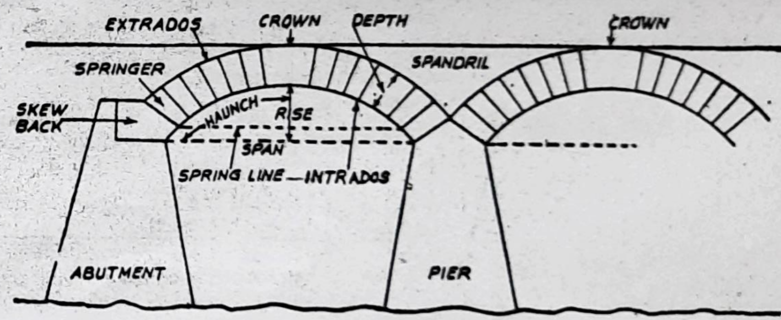

Fig. 2·17. Parts of an arch.

1. **Abutment.** The part of the wall on which the arch rests, is called *abutment.*

2. **Span.** The clear horizontal distance between two supports of an arch, is called *span.*

3. **Intrados.** The inner curve of the arch, is called *intrados.*

4. **Extrados.** The external curve of the arch, is called *extrados.*

5. **Crown.** The highest point of the extrados, is called *crown.*

6. **Rise.** The vartical distance between the highest point on the intrados and the springing line is called, a *rise.*

7. **Springing point** The point of intersection of the intrados and skew back, is called *springing point.*

8. **Voussoirs.** Wedge shaped masonry forming the arch are called *voussoirs.*

9. **Key stone.** The highest central wedge shaped masonry used in the arch, is called *key stone.*

10. **Depth.** The perpendicular distance between the extrados and intrados, is called depth of the arch.

11. **Spandril.** The trianglar space between the back of the arch ring *i.e.*, the space between the tangent at the crown and the extrados, is called *spandril.*

12. **Haunch.** The bottom half portion of the arch between the skew back and the crown, is called *haunch.*

13. **Skew back.** The splayed surface of the abutment on which the end of the arch rests, is called *skew back.*

2·29. Lintels

The horizontal structural member spanning an opening to support the load of the structure coming over it, is called a *Lintel.*

The following types of lintels are in common use.

1. **Wooden lintel.** A sound and hard timber plank is used to span over the opening and over wooden lintel, masonry is constructed.

2. **Brick lintel.** Brick lintels are used for openings up to one metre spans.

3. **Stone lintel.** A single piece of stone is used over the opening.

2·30 Classification of doors according to movements
(U.P.S.C. Civil Services Exam., 1983)

The doors may be classified according to their movements as under :

1. **Swinging doors.** This type of door may be single swinging or double swinging.

2. **Revolving doors.** This type of door is centrally pivoted.

3. **Sliding doors.** This type of door slides horizontally or upward-downward.

4. **Rolling shutter doors.** This type of door may be rolled easily whenever required.

5. **Folding doors.** This type of door which may be folded, is used to cover large opening.

6. **Collapsible doors.** This type of door rolls along small channels fixed at the top.

2·31. Classification of doors based on their construction
(U.P.S.C. Civil Services Exam., 1983)

The doors may be classified as under :

1. **Ledged doors.** A ledged door is made up of timber boards (battens) and fixed in position by horizontal members known as ledges.

2. **Ledged and braced doors.** When battens are fixed in position by diagonal members known as braces, the doors are called ledges braced doors.

3. **Framed and pannelled door.** This type of door is made of a frame work in which panels are fixed.

4. **Glazed or sash doors.** The type of door is made of fully or partly glazed and partly panelled portion.

5. **Louvered doors.** This type of door is provided with louvers which may be opened and closed easily.

6. **Flush doors.** This type of door is made of a frame work of timber styles and rails are provided.

7. **Revolving doors.** This type of door is made of central supporting shaft and four radiating shutters are attached to the central shaft.

2·32. Types of Floors

The commonly used floors are :

1. **Basement or ground timber floors.** This consists of a number of dwarf walls constructed 1·5 m apart over which timber floor is supported. Under the timber, sand is filled over a layer of cement concrete. These are suitable for theatres.

2. **Filler joist floor.** This consists of small sections of rolled steel joists encased in the concrete. The joints are supported on walls or on beams.

3. **Jackarch floor.** This consists of bricks or concrete jacks which are supported on arches provided between the lower flange of

rolled steel joists, placed 1·5 m apart. The rise of the arch is generally kept 1/12 of the span.

4. **Double flag stone floor**. This consists of steel beams spaced 3 m apart and joists placed over beams at right angles. Flag stones are placed on the lower flanges and also on upper flanges. The empty space between flag stones is filled with sand.

5. **R.C.C. floor.** Reinforced cement concrete slab is used in R.C.C. floor, thickness being guided by the superimposed loads on span and the concrete mix.

6. **Flat slab floor.** This type of floor consists of flat slab which is directly supported on the columns without any intermediate beam.

7. **Hollow tiled ribbed floor.** This type of floor is made of hollow tiled ribbed floor for reducing the weight. It is suitable for fire proofing and dam proofing.

2·33. Requirements of good stairs
(U.P.S.C. Engg. Services Exam., 1979)

A good stair should provide an easy, quick and safe mode of communication between the various floors of the building. General requirements of good stairs are :

1. **Location.** It should preferably be located centrally, ensuring sufficient light and ventilation.

2. **Width of stair.** The width of stairs for public buildings should be 1·8 m and for residential buildings 0·9 m.

3. **Length.** The flight of the stairs should be restricted to a maximum of 12 and minimum of 3 steps.

4. **Pitch of stair.** The pitch of long stairs should be made flatter by introducing landings. The slope should not exceed 40° and should not be less than 25°.

5. **Head room.** The distance between the tread and soffit of the flight immediately above it, should not be less than 2·14 m.

6. **Materials.** Fire resisting materials should be used.

7. **Balustrade.** All open well stairs should be provided with balustrades, to avoid accidents.

8. **Landing.** The width of the landing should not be less than the width of the stair.

9. **Winders.** These should be avoided and, if found necessary, may be provided at lower end of the flight.

10. **Step proportions.** The ratio of the going and the rise of a step should be well proportioned to ensure a comfortable access to the stair way.

Following empirical rules may be followed :

(*i*) Treads in cm + 2 (rise in cm) = 60

(*ii*) Treads in cm × (rise in cm) = 400 to 410 Appx.

(*iii*) Standard sizes : tread 30 cm, rise 14 cm.

Generally adopted sizes of steps are :

(*a*) Public buildings : 27 cm × 15 om to 30 cm × 14 cm

(*b*) Residential buildings : 25 cm × 16 cm.

2·34. Types of Stairs

The stairs may be of the following types :

1. **Straight flight stairs.** This type of stair consists of a single flight with or without landings in between.

2. **Quarter turn stairs.** This type of stairs is provided at 90° turn by introducing a quarter space landing or winders at the junction.

3. **Half turn stairs.** The stairs which change their direction through 180°, are called half turn stairs. These may be further divided into two types :

(*i*) **Dog-legged stairs.** It consists of two straight flights of steps with an abrupt turn between them. Usually, a level landing is placed across the two flights at the changes of direction. This type of stairs are useful where width of the stair case, is sufficient to accommodate two widths of stairs.

(*ii*) **Open-newel stairs.** It consits of two or more straight flights arranged in such a manner that a clear space, called, '*a well*', is provided between the backward and the forward flights. If the size of stairs case hall does not permit to accommodate the number of stairs in two flights, without exceeding the permissible maximum limit of steps in each flight, a short flight consisting of 3 to 5 steps may be provided along the width of the stair case. Quarter landing spaces are provided at each end of the short flight.

4. **Geometerical stairs.** This type of stairs is similar to the open-newel stair with the difference that the open well between the forward and the backward flight is curved. In such stairs the change in direction is obtained by providing winders. Better skill is needed to construct geometrical stairs. These are weaker than open newel stairs.

5. **Bifurcating stairs.** This type of stairs consists of a wide flight at the start and is divided into two narrow flights at the midlanding. The two narrow flights begin from either side of the midlanding.

6. **Circular or spiral stairs.** This type of stair consists of steps radiating from a newel post, in the form of winders.

2·35. Important Technical terms used in stairs
(U.P.S.C. Engg. Services Exam., 1980)

1. **Stringers.** The sloping wooden members which are provided to support the ends of steps, are called *stringers*. For stairs of average width, two stringers are provided one adjacent to the wall and other outside. For wider stairs, an additional stringer may be provided in the middle.

2. **Baluster.** The wooden, metal or masonry vertical member which is provided to support a hand rail, is called a *baluster*.

3. **Hand rail.** The wooden or metallic rail, generally provided on the side of stairs at about waist height, to help the users, is called *hand rail*.

4. **Balustrade.** The combined frame work of hand-rail and balusters, provided to perform the function of a fence for the users, is called *balustrade*.

5. **Winders.** The angular or radiating steps which are provided for changing the direction of a stair, are called *winders*.

6. **Head room.** The minimum clear distance of 2·14 m between the tread and soffit of the flight immediately above it, is called *head room*.

7. **Nosing.** The outer projection of a tread, is known as *nosing*.

8. **Newel post.** The vertical member placed at the ends of flights to join the ends of stringers and hand roils, is called *newel post*.

9. **Tread.** The horizontal upper part of a step which is used to rest the foot while ascending or descending the stairs, is called *tread*.

10. **Rise.** The vertical distance between the surfaces of two consecutive steps, is called *rise*.

11. **Pitch.** The angle of inclination of the flight of the stair, with the floor, is called the *pitch*.

12. **Scotia.** The moulding provided under nosing to beautify the elevation of the step, is called *scotia*.

13. **Soffit.** The under surface of a stair, is called *soffit*.

2·36. Shoring

The arrangement employed to prevent a damaged structure due to either foundation settlement or other reasons from collapse, is called *shoring*. It is also used for providing temporary support to a structure which is being remodelled.

The shores are of three types.

1. **Racking shores.** In this type, notches are cut in the walls of the building and inclined posts are inserted to carry the weight of that part of the wall above the supports.

2. **Horizontal or flying shores.** The shores which are employed to support the walls of adjoining property while demolishing the building, are called harizontal or flying shores.

3. **Vertical or dead shore.** The vertical shores used to support walls temporarily are called *vertical or dead shores*.

2·37. Under pinning

The operation of providing new permanent foundation, is known as *under pinning*.

The under pinning may be done by the following methods.

1. **Pit under pinning.** In this method a pit is dug to expose the foundation to be remodelled, the old foundation is either removed completely or strengthened suitably.

2. **Pier under pinning.** In this method of under-pinning, piers under foundations of structures, are installed, filled with concrete and wedged up to transfer the load to a new pier. This method is most suitable in dry ground. In pier under pinning, proper care must be taken to prevent loss of ground installing the sheeting, otherwise the building structure may sink. The least size of the under pinning pits to provide working place, for workers is 1 m×1·3 m. The pits are sunk to a stratum strong enough to support the desired load.

3. **Pile under pinning.** In this method, piles are jacked into the ground with ease for under pinning buildings where underlying ground has water bearing strata.

2·38. Scaffolding

The temporary erection provided to support a number of platforms at different levels for the convenience of workers, is called *scaffolding*.

The commonly used scaffolds are :

1. **Single scaffolding.** It consists of vertical members firmly fixed in ground at 2·5 m to 3·0 m apart. These standards are connected together by ledgers, the horizontal members, at every 1·3 to 1·6 m. The ledgers carry put logs, transverse pieces at right angles to the walls, to support the working platform.

2. **Double scaffold.** In this type double scaffolds are provided with ledgers and braces, one close to the wall and the other at a distance of 1·5 m from the first.

3. **Cantilever scaffold.** In this type, the scaffolds are cantilevered and supported by a number of needles which are provided at floor levels or through holes made in the wall.

4. **Suspended scaffold.** This type of scaffold which is very light, consists of a working platform suspended from the roof with the help of ropes, chains or wires. This may be raised or lowered according to the working area.

5. **Trestle scaffold.** This type of scaffold consists of a ladder or tripod carrying a working platform on their tops.

6. **Steel scaffold.** The scaffold in which steel pipes are used, is called *steel scaffold.* These can be erected rapidly and are less deterioted.

Example 2·1. *Design the foundotion of a residential building three storey high. The foundation is to rest on sandy soil having an angle of repose of 30 degrees and the safe bearing power of 16 tonnes per sq. m. The soil weighs 1680 kg. per cu. m. The total dead and live load per metre length of the wall is 12·266 tonnes. Assume 1 : 3 lime concrete to be used for foundation bed and the bed block projects 0·15 m from lowest course of the footing. The safe modulus of rupture of the concrete mix used is 1·55 kg/sq. cm. The walls are 30 cm thick. Give the diagram of foundation.*

(U.P.S.C. Civil Services Exam., 1980)

Solution.

Weight of the masonry wall per metre length $=12{\cdot}266\ t$.

Self weight of the foundation @ 10% of the weight of wall $=1{\cdot}2266$.

Total load 'W_s' per metre length on the soil $=13{\cdot}493\ t=13{\cdot}5\ t$.

Bearing capacity 'p' of the soil $=16\ t/m^2$.

Width of the foundation 'b' $=\frac{W}{p}=\frac{13{\cdot}5}{16}=0{\cdot}843$ m

$=85$ cm.

From the consideration of concrete block projection width

$$b=2T+2j$$

where T = wall thickness

j = block projection

$\therefore$ $b=2\times30+2\times15=90$ cm.

Adopt a width of foundation equal to 100 cm.

Debth of foundation (b).

By Rankine's formula,

$$b=\frac{W}{AW_s}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2 \qquad \ldots(i)$$

where W_s is weight of soil.

Substituting the values in eqn. (i), we get

$$b=\frac{13500}{0{\cdot}90\times1\times1680}\left(\frac{1-\sin 30°}{1+\sin 30°}\right)^2$$

$$=\frac{13500}{0{\cdot}90\times1\times1680}\left(\frac{1-\frac{1}{2}}{1+\frac{1}{2}}\right)^2$$

$=0{\cdot}9921\ m$ say 100 cm.

Depth of concrete block (1 : 3 lime concrete)

$$d=\sqrt{\frac{6pj^2}{2m}} \qquad \ldots(ii)$$

where p = upward soil reaction in kg/cm²

$=\frac{13600}{100\times100}=1{\cdot}35$ kg/cm²

$j=15$ cm.

m = modulus of rupture of concrete in kg/cm²

$=1{\cdot}55$ kg/cm²

Substituting the values in eqn. (ii) we get

$\therefore$ $d=\sqrt{\frac{6\times1{\cdot}35\times15^2}{2\times1{\cdot}25}}$

$=24{\cdot}25$ cm say 30 cm.

The diagram of the foundation is shown in Fig. 2·18.

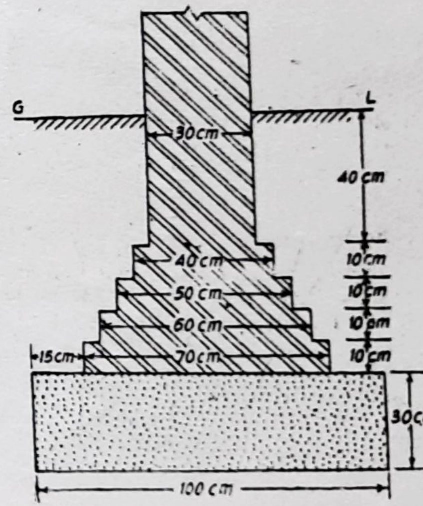

Fig. 2·18.