

# BASIC CIVIL ENGINEERING

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# **UNIT - I**

## **CIVIL ENGINEERING MATERIALS**



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# Traditional Materials

Stones, bricks, cement, lime and timber are the traditional materials used for civil engineering constructions for several centuries. In this chapter types, properties, tests and uses of these materials is explained.

## 1.1 STONES

Stone is a 'naturally available building material' which has been used from the early age of civilization. It is available in the form of rocks, which is cut to required size and shape and used as building block. It has been used to construct small residential buildings to large palaces and temples all over the world. Red Fort, Taj Mahal, Vidhan Sabha at Bangalore and several palaces of medieval age all over India are the famous stone buildings.

### 1.1.1 Type of Stones

Stones used for civil engineering works may be classified in the following three ways:

- Geological
- Physical
- Chemical

#### Geological Classification

Based on their origin of formation stones are classified into three main groups—Igneous, sedimentary and metamorphic rocks.

(i) **Igneous Rocks:** These rocks are formed by cooling and solidifying of the rock masses from their molten magmatic condition of the material of the earth. Generally igneous rocks are strong and durable. Granite, trap and basalt are the rocks belonging to this category, Granites are formed by slow cooling of the lava under thick cover on the top. Hence they have crystalline surface. The cooling of lava at the top surface of earth results into non-crystalline and glassy texture. Trap and basalt belong to this category.

(ii) **Sedimentary Rocks:** Due to weathering action of water, wind and frost existing rocks disintegrate. The disintegrated material is carried by wind and water; the water being most powerful medium. Flowing water deposits its suspended materials at some points of obstacles to its flow. These deposited layers of materials get consolidated under pressure and by heat. Chemical agents also contribute to the cementing of the deposits. The rocks thus formed are more uniform, fine grained and compact in their nature. They represent a bedded or stratified structure in general. Sand stones, lime stones, mud stones etc. belong to this class of rock.

(iii) **Metamorphic Rocks:** Previously formed igneous and sedimentary rocks under go changes due to metamorphic action of pressure and internal heat. For example due to metamorphic action granite becomes gneisses, trap and basalt change to schist and laterite, lime stone changes to marble, sand stone becomes quartzite and mud stone becomes slate.

### Physical Classification

Based on the structure, the rocks may be classified as:

- Stratified rocks
- Unstratified rocks

(i) **Stratified Rocks:** These rocks are having layered structure. They possess planes of stratification or cleavage. They can be easily split along these planes. Sand stones, lime stones, slate etc. are the examples of this class of stones.

(ii) **Unstratified Rocks:** These rocks are not stratified. They possess crystalline and compact grains. They cannot be split in to thin slab. Granite, trap, marble etc. are the examples of this type of rocks.

(iii) **Foliated Rocks:** These rocks have a tendency to split along a definite direction only. The direction need not be parallel to each other as in case of stratified rocks. This type of structure is very common in case of metamorphic rocks.

### Chemical Classification

On the basis of their chemical composition engineers prefer to classify rocks as:

- Silicious rocks
- Argillaceous rocks and
- Calcareous rocks

(i) **Silicious rocks:** The main content of these rocks is silica. They are hard and durable. Examples of such rocks are granite, trap, sand stones etc.

(ii) **Argillaceous rocks:** The main constituent of these rocks is argil *i.e.*, clay. These stones are hard and durable but they are brittle. They cannot withstand shock. Slates and laterites are examples of this type of rocks.

(iii) **Calcareous rocks:** The main constituent of these rocks is calcium carbonate. Limestone is a calcareous rock of sedimentary origin while marble is a calcareous rock of metamorphic origin.

### 1.1.2 Properties of Stones

The following properties of the stones should be looked into before selecting them for engineering works:

(i) **Structure:** The structure of the stone may be stratified (layered) or unstratified. Structured stones should be easily dressed and suitable for super structure. Unstratified stones are hard and difficult to dress. They are preferred for the foundation works.

(ii) **Texture:** Fine grained stones with homogeneous distribution look attractive and hence they are used for carving. Such stones are usually strong and durable.

(iii) **Density:** Denser stones are stronger. Light weight stones are weak. Hence stones with specific gravity less than 2.4 are considered unsuitable for buildings.

(iv) **Appearance:** A stone with uniform and attractive colour is durable, if grains are compact. Marble and granite get very good appearance, when polished. Hence they are used for face works in buildings.

(v) **Strength:** Strength is an important property to be looked into before selecting stone as building block. Indian standard code recommends, a minimum crushing strength of  $3.5 \text{ N/mm}^2$  for any building block. Table 1.1 shows the crushing strength of various stones. Due to non-uniformity of the material, usually a factor of safety of 10 is used to find the permissible stress in a stone. Hence even laterite can be used safely for a single storey building, because in such structures expected load can hardly give a stress of  $0.15 \text{ N/mm}^2$ . However in stone masonry buildings care should be taken to check the stresses when the beams (Concentrated Loads) are placed on laterite wall.

**Table 1.1.** Crushing strength of common building stones

<i>Name of Stone</i>	<i>Crushing Strength in <math>\text{N/mm}^2</math></i>
Trap	300 to 350
Basalt	153 to 189
Granite	104 to 140
Slate	70 to 210
Marble	72
Sand stone	65
Lime stone	55
Laterite	1.8 to 3.2

(vi) **Hardness:** It is an important property to be considered when stone is used for flooring and pavement. Coefficient of hardness is to be found by conducting test on standard specimen in Dory's testing machine. For road works coefficient of hardness should be at least 17. For building works stones with coefficient of hardness less than 14 should not be used.

(vii) **Percentage wear:** It is measured by attrition test. It is an important property to be considered in selecting aggregate for road works and railway ballast. A good stone should not show wear of more than 2%.

(viii) **Porosity and Absorption:** All stones have pores and hence absorb water. The reaction of water with material of stone cause disintegration. Absorption test is specified as percentage of water absorbed by the stone when it is immersed under water for 24 hours. For a good stone it should be as small as possible and in no case more than 5.

(ix) **Weathering:** Rain and wind cause loss of good appearance of stones. Hence stones with good weather resistance should be used for face works.

(x) **Toughness:** The resistance to impact is called toughness. It is determined by impact test. Stones with toughness index more than 19 are preferred for road works. Toughness index 13 to 19 are considered as medium tough and stones with toughness index less than 13 are poor stones.

(xi) **Resistance to Fire:** Sand stones resist fire better. Argillaceous materials, though poor in strength, are good in resisting fire.

(xii) **Ease in Dressing:** Cost of dressing contributes to cost of stone masonry to a great extent. Dressing is easy in stones with lesser strength. Hence an engineer should look into sufficient strength rather than high strength while selecting stones for building works.

(xiii) **Seasoning:** The stones obtained from quarry contain moisture in the pores. The strength of the stone improves if this moisture is removed before using the stone. The process of removing moisture from pores is called seasoning. The best way of seasoning is to allow it to the action of nature for 6 to 12 months. This is very much required in the case of laterite stones.

### 1.1.3 Requirements of Good Building Stones

The following are the requirements of good building stones:

(i) **Strength:** The stone should be able to resist the load coming on it. Ordinarily this is not of primary concern since all stones are having good strength. However in case of large structure, it may be necessary to check the strength.

(ii) **Durability:** Stones selected should be capable of resisting adverse effects of natural forces like wind, rain and heat.

(iii) **Hardness:** The stone used in floors and pavements should be able to resist abrasive forces caused by movement of men and materials over them.

(iv) **Toughness:** Building stones should be tough enough to sustain stresses developed due to vibrations. The vibrations may be due to the machinery mounted over them or due to the loads moving over them. The stone aggregates used in the road constructions should be tough.

(v) **Specific Gravity:** Heavier variety of stones should be used for the construction of dams, retaining walls, docks and harbours. The specific gravity of good building stone is between 2.4 and 2.8.

(vi) **Porosity and Absorption:** Building stone should not be porous. If it is porous rain water enters into the pore and reacts with stone and crumbles it. In higher altitudes, the freezing of water in pores takes place and it results into the disintegration of the stone.

(vii) **Dressing:** Giving required shape to the stone is called dressing. It should be easy to dress so that the cost of dressing is reduced. However the care should be taken so that, this is not be at the cost of the required strength and the durability.

(viii) **Appearance:** In case of the stones to be used for face works, where appearance is a primary requirement, its colour and ability to receive polish is an important factor.

(ix) **Seasoning:** Good stones should be free from the quarry sap. Laterite stones should not be used for 6 to 12 months after quarrying. They are allowed to get rid of quarry sap by the action of nature. This process of removing quarry sap is called seasoning.

(x) **Cost:** Cost is an important consideration in selecting a building material. Proximity of the quarry to building site brings down the cost of transportation and hence the cost of stones comes down.

However it may be noted that not a single stone can satisfy all the requirements of a good building stones, since one requirement may contradict another. For example, strength and durability requirement contradicts ease of dressing requirement. Hence it is necessary that site engineer looks into the properties required for the intended work and selects the stone.

#### 1.1.4 Tests on Stones

To ascertain the required properties of stones, the following tests can be conducted:

- (i) crushing strength test
- (ii) water absorption test
- (iii) abrasion test
- (iv) impact test
- (v) acid test.

(i) **Crushing Strength Test:** For conducting this test, specimen of size  $40 \times 40 \times 40$  mm are prepared from parent stone. Then the sides are finely dressed and placed in water for 3 days. The saturated specimen is provided with a layer of plaster of paris on its top and bottom surfaces to get even surface so that load applied is distributed uniformly. Uniform load distribution can be obtained satisfactorily by providing a pair of 5 mm thick plywood instead of using plaster of paris layer also. The specimen so placed in the compression testing machine is loaded at the rate of  $14 \text{ N/mm}^2$  per minute. The crushing load is noted. Then crushing strength is equal to the crushing load divided by the area over which the load is applied. At least three specimen should be tested and the average should be taken as crushing strength.

(ii) **Water Absorption Test:** For this test cube specimen weighing about 50 grams are prepared and the test is carried out in the steps given below:

- (a) Note the weight of dry specimen as  $W_1$ .
- (b) Place the specimen in water for 24 hours.
- (c) Take out the specimen, wipe out the surface with a piece of cloth and weigh the specimen. Let its weight be  $W_2$ .
- (d) Suspend the specimen freely in water and weight it. Let its weight be  $W_3$ .
- (e) Place the specimen in boiling water for 5 hours. Then take it out, wipe the surface with cloth and weigh it. Let this weight be  $W_4$ . Then,

$$\text{Percentage absorption by weight} = \frac{W_2 - W_1}{W_1} \times 100 \quad \dots(1)$$

$$\text{Percentage absorption by volume} = \frac{W_2 - W_1}{W_2 - W_3} \times 100 \quad \dots(2)$$

$$\text{Percentage porosity by volume} = \frac{W_4 - W_1}{W_2 - W_3} \times 100 \quad \dots(3)$$

$$\text{Density} = \frac{W_1}{W_2 - W_1} \quad \dots(4)$$

$$\text{Specific gravity} = \frac{W_1}{W_2 - W_3} \quad \dots(5)$$

$$\begin{aligned} \therefore \text{ Saturation coefficient} &= \frac{\text{Water absorption}}{\text{Total porosity}} \\ &= \frac{W_2 - W_1}{W_4 - W_1} \end{aligned}$$

(iii) **Abrasion Test:** This test is carried out on stones which are used as aggregates for road construction. The test result indicate the suitability of stones against the grinding action under traffic. Any one of the following test may be conducted to find out the suitability of aggregates:

- (i) Los Angeles abrasion test
- (ii) Deval abrasion test
- (iii) Dorry's abrasion test.

However Los Angeles abrasion test is preferred since these test results are having good correlation with the performance of the pavements.

The Los Angeles apparatus [Fig. 1.1] consists of a hollow cylinder 0.7 m inside diameter and 0.5 m long with both ends closed. It is mounted on a frame so that it can be rotated about horizontal axis. IS code has standardised the test procedure for different gradation of specimen. Along with specified weight of specimen a specified number of cast iron balls of 48 mm diameter are placed in the cylinder.

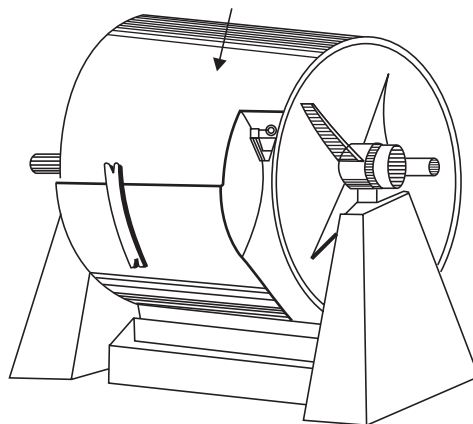


Fig. 1.1. Los Angeles testing machine

Then the cylinder is rotated at a speed of 30 to 33 rpm for specified number of times (500 to 1000). Then the aggregate is removed and sieved on 1.7 mm. IS sieve. The weight of aggregate passing is found. Then Los Angeles value is found as

$$= \frac{\text{Weight of aggregate passing through sieve}}{\text{Original weight}} \times 100.$$

The following values are recommended for road works:

For bituminous mixes – 30%

For base course – 50%

(iv) **Impact Test:** The resistance of stones to impact is found by conducting tests in impacting testing machine (Fig. 1.2). It consists of a frame with guides in which a metal hammer weighing 13.5 to 15 kg can freely fall from a height of 380 mm.

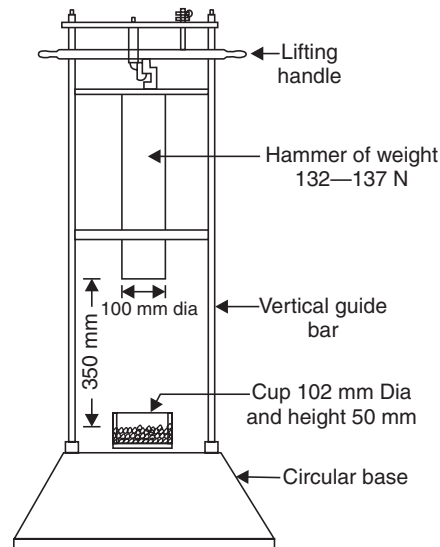


Fig. 1.2. Aggregate impact testing machine

Aggregates of size 10 mm to 12.5 mm are filled in cylinder in 3 equal layers; each layer being tamped 25 times. The same is then transferred to the cup and again tamped 25 times. The hammer is then allowed to fall freely on the specimen 15 times. The specimen is then sieved through 2.36 mm sieve. Then,

$$\text{Impact value} = \frac{W_2}{W_1}$$

where  $W_2$  = weight of fines

$W_1$  = original weight.

The recommended impact values for various works are:

(i) for wearing course  $\geq$  30%



- (ii) for bituminous mechadam  $\geq 35\%$
- (iii) for water bound mechadam  $\geq 40\%$

(v) **Acid Test:** This test is normally carried out on sand stones to check the presence of calcium carbonate, which weakens the weather resisting quality. In this test, a sample of stone weighing about 50 to 100 gm is taken and kept in a solution of one per cent hydrochloric acid for seven days. The solution is agitated at intervals. A good building stone maintains its sharp edges and keeps its surface intact. If edges are broken and powder is formed on the surface, it indicates the presence of calcium carbonate. Such stones will have poor weather resistance.

### 1.1.5 Uses of Stones

Stones are used in the following civil engineering constructions:

- (i) Stone masonry is used for the construction of foundations, walls, columns and arches.
- (ii) Stones are used for flooring.
- (iii) Stone slabs are used as damp proof courses, lintels and even as roofing materials.
- (iv) Stones with good appearance are used for the face works of buildings. Polished marbles and granite are commonly used for face works.
- (v) Stones are used for paving of roads, footpaths and open spaces round the buildings.
- (vi) Stones are also used in the constructions of piers and abutments of bridges, dams and retaining walls.
- (vii) Crushed stones with gravel are used to provide base course for roads. When mixed with tar they form finishing coat.
- (viii) Crushed stones are used in the following works also:
  - (a) As a basic inert material in concrete
  - (b) For making artificial stones and building blocks
  - (c) As railway ballast.

### 1.1.6 Common Building Stones

The following are the some of commonly used stones:

- |                     |                   |
|---------------------|-------------------|
| (i) Basalt and trap | (ii) Granite      |
| (iii) Sand stone    | (iv) Slate        |
| (v) Laterite        | (vi) Marble       |
| (vii) Gneiss        | (viii) Quartzite. |

Their qualities and uses are explained below:

(i) **Basalt and Trap:** The structure is medium to fine grained and compact. Their colour varies from dark gray to black. Fractures and joints are common. Their weight varies from  $18 \text{ kN/m}^3$  to  $29 \text{ kN/m}^3$ . The compressive strength varies from 200 to  $350 \text{ N/mm}^2$ . These are igneous rocks. They are used as road metals, aggregates for concrete. They are also used for rubble masonry works for bridge piers, river walls and dams. They are used as pavement.

(ii) **Granite:** Granites are also igneous rocks. The colour varies from light gray to pink. The structure is crystalline, fine to coarse grained. They take polish well. They are hard durable. Specific gravity is from 2.6 to 2.7 and compressive strength is 100 to 250 N/mm<sup>2</sup>. They are used primarily for bridge piers, river walls, and for dams. They are used as kerbs and pedestals. The use of granite for monumental and institutional buildings is common. Polished granites are used as table tops, cladding for columns and wall. They are used as coarse aggregates in concrete.

(iii) **Sand stone:** These are sedimentary rocks, and hence stratified. They consist of quartz and feldspar. They are found in various colours like white, grey, red, buff, brown, yellow and even dark gray. The specific gravity varies from 1.85 to 2.7 and compressive strength varies from 20 to 170 N/mm<sup>2</sup>. Its porosity varies from 5 to 25 per cent. Weathering of rocks renders it unsuitable as building stone. It is desirable to use sand stones with silica cement for heavy structures, if necessary. They are used for masonry work, for dams, bridge piers and river walls.

(iv) **Slate:** These are metamorphic rocks. They are composed of quartz, mica and clay minerals. The structure is fine grained. They split along the planes of original bedding easily. The colour varies from dark gray, greenish gray, purple gray to black. The specific gravity is 2.6 to 2.7. Compressive strength varies from 100 to 200 N/mm<sup>2</sup>. They are used as roofing tiles, slabs, pavements etc.

(v) **Laterite:** It is a metamorphic rock. It is having porous and sponges structure. It contains high percentage of iron oxide. Its colour may be brownish, red, yellow, brown and grey. Its specific gravity is 1.85 and compressive strength varies from 1.9 to 2.3 N/mm<sup>2</sup>. It can be easily quarried in blocks. With seasoning it gains strength. When used as building stone, its outer surface should be plastered.

(vi) **Marble:** This is a metamorphic rock. It can take good polish. It is available in different pleasing colours like white and pink. Its specific gravity is 2.65 and compressive strength is 70–75 N/mm<sup>2</sup>. It is used for facing and ornamental works. It is used for columns, flooring, steps etc.

(vii) **Gneiss:** It is a metamorphic rock. It is having fine to coarse grains. Alternative dark and white bands are common. Light grey, pink, purple, greenish gray and dark grey coloured varieties are available. These stones are not preferred because of deleterious constituents present in it. They may be used in minor constructions. However hard varieties may be used for buildings. The specific gravity varies from 2.5 to 3.0 and crushing strength varies from 50 to 200 N/mm<sup>2</sup>.

(viii) **Quartzite:** Quartzites are metamorphic rocks. The structure is fine to coarse grained and often granular and branded. They are available in different colours like white, gray, yellowish. Quartz is the chief constituent with feldspar and mica in small quantities. The specific gravity varies from 2.55 to 2.65. Crushing strength varies from 50 to 300 N/mm<sup>2</sup>. They are used as building blocks and slabs. They are also used as aggregates for concrete.

## 1.2 BRICKS

Brick is obtained by moulding good clay into a block, which is dried and then burnt. This is the oldest building block to replace stone. Manufacture of brick started with hand moulding, sun drying and burning in clamps. A considerable amount of technological development has taken place with better

knowledge about to properties of raw materials, better machinaries and improved techniques of moulding drying and burning.

The size of the bricks are of 90 mm × 90 mm × 90 mm and 190 mm × 90 mm × 40 mm. With mortar joints, the size of these bricks are taken as 200 mm × 100 mm × 100 mm and 200 mm × 100 mm × 50 mm. However the old size of  $8\frac{3}{4} \times 4\frac{1}{2} \times 2\frac{5}{8}$  giving a masonry size of  $9'' \times 4\frac{1}{2}'' \times 3''$  is still commonly used in India.

### 1.2.1 Types of Bricks

Bricks may be broadly classified as:

- (i) Building bricks
- (ii) Paving bricks
- (iii) Fire bricks
- (iv) Special bricks.

(i) **Building Bricks:** These bricks are used for the construction of walls.

(ii) **Paving Bricks:** These are vitrified bricks and are used as pavers.

(iii) **Fire Bricks:** These bricks are specially made to withstand furnace temperature. Silica bricks belong to this category.

(iv) **Special Bricks:** These bricks are different from the commonly used building bricks with respect to their shape and the purpose for which they are made. Some of such bricks are listed below:

- (a) Specially shaped bricks
- (b) Facing bricks
- (c) Perforated building bricks
- (d) Burnt clay hollow bricks
- (e) Sewer bricks
- (f) Acid resistant bricks.

(a) **Specially Shaped Bricks:** Bricks of special shapes are manufactured to meet the requirements of different situations. Some of them are shown in Fig. 1.3.

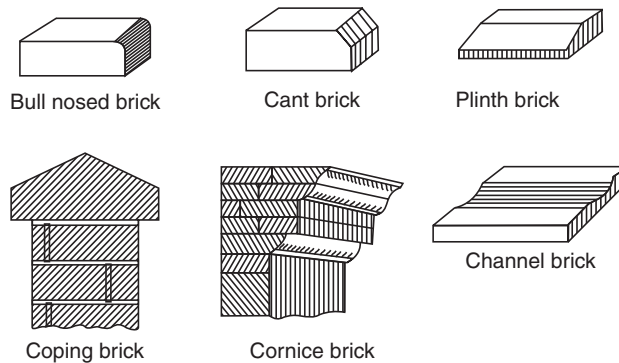


Fig. 1.3. Special shaped bricks

- (b) **Facing Bricks:** These bricks are used in the outer face of masonry. Once these bricks are provided, plastering is not required. The standard size of these bricks are  $190 \times 90 \times 90$  mm or  $190 \times 90 \times 40$  mm.
- (c) **Perforated Building Bricks:** These bricks are manufactured with area of perforation of 30 to 45 per cent. The area of each perforation should not exceed  $500 \text{ mm}^2$ . The perforation should be uniformly distributed over the surface. They are manufactured in the size  $190 \times 190 \times 90$  mm and  $290 \times 90 \times 90$  mm.
- (d) **Burn't Clay Hollow Bricks:** Figure 1.4 shows a burnt clay hollow brick. They are light in weight. They are used for the construction of partition walls. They provide good thermal insulation to buildings. They are manufactured in the sizes  $190 \times 190 \times 90$  mm,  $290 \times 90 \times 90$  mm and  $290 \times 140 \times 90$  mm. The thickness of any shell should not be less than 11 mm and that of any web not less than 8 mm.

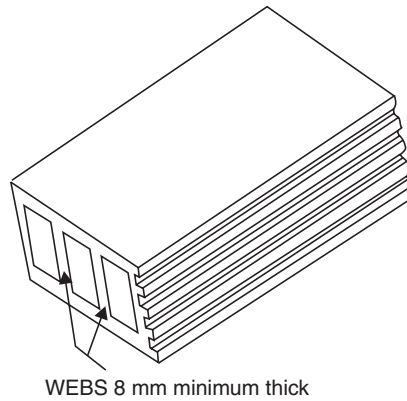


Fig. 1.4. Hollow bricks

- (e) **Sewer Bricks:** These bricks are used for the construction of sewage lines. They are manufactured from surface clay, fire clay shale or with the combination of these. They are manufactured in the sizes  $190 \times 90 \times 90$  mm and  $190 \times 90 \times 40$  mm. The average strength of these bricks should be a minimum of  $17.5 \text{ N/mm}^2$ . The water absorption should not be more than 10 per cent.
- (f) **Acid Resistant Bricks:** These bricks are used for floorings likely to be subjected to acid attacks, lining of chambers in chemical plants, lining of sewers carrying industrial wastes etc. These bricks are made of clay or shale of suitable composition with low lime and iron content, flint or sand and vitrified at high temperature in a ceramic kiln.

### 1.2.2 Properties of Bricks

The following are the required properties of good bricks:

- (i) **Colour:** Colour should be uniform and bright.
- (ii) **Shape:** Bricks should have plane faces. They should have sharp and true right angled corners.
- (iii) **Size:** Bricks should be of standard sizes as prescribed by codes.

(iv) **Texture:** They should possess fine, dense and uniform texture. They should not possess fissures, cavities, loose grit and unburnt lime.

(v) **Soundness:** When struck with hammer or with another brick, it should produce metallic sound.

(vi) **Hardness:** Finger scratching should not produce any impression on the brick.

(vii) **Strength:** Crushing strength of brick should not be less than  $3.5 \text{ N/mm}^2$ . A field test for strength is that when dropped from a height of 0.9 m to 1.0 m on a hard ground, the brick should not break into pieces.

(viii) **Water Absorption:** After immersing the brick in water for 24 hours, water absorption should not be more than 20 per cent by weight. For class-I works this limit is 15 per cent.

(ix) **Efflorescence:** Bricks should not show white patches when soaked in water for 24 hours and then allowed to dry in shade. White patches are due to the presence of sulphate of calcium, magnesium and potassium. They keep the masonry permanently in damp and wet conditions.

(x) **Thermal Conductivity:** Bricks should have low thermal conductivity, so that buildings built with them are cool in summer and warm in winter.

(xi) **Sound Insulation:** Heavier bricks are poor insulators of sound while light weight and hollow bricks provide good sound insulation.

(xii) **Fire Resistance:** Fire resistance of bricks is usually good. In fact bricks are used to encase steel columns to protect them from fire.

### 1.2.3 Tests on Bricks

The following *laboratory tests* may be conducted on the bricks to find their suitability:

- (i) Crushing strength
- (ii) Absorption
- (iii) Shape and size and
- (iv) Efflorescence.

(i) **Crushing Strength:** The brick specimen are immersed in water for 24 hours. The frog of the brick is filled flush with 1:3 cement mortar and the specimen is stored in damp jute bag for 24 hours and then immersed in clean water for 24 hours. The specimen is placed in compression testing machine with 6 mm plywood on top and bottom of it to get uniform load on the specimen. Then load is applied axially at a uniform rate of  $14 \text{ N/mm}^2$ . The crushing load is noted. Then the crushing strength is the ratio of crushing load to the area of brick loaded. Average of five specimen is taken as the crushing strength.

(ii) **Absorption Test:** Brick specimen are weighed dry. Then they are immersed in water for a period of 24 hours. The specimen are taken out and wiped with cloth. The weight of each specimen in wet condition is determined. The difference in weight indicate the water absorbed. Then the percentage absorption is the ratio of water absorbed to dry weight multiplied by 100. The average of five specimen is taken. This value should not exceed 20 per cent.

(iii) **Shape and Size:** Bricks should be of standard size and edges should be truly rectangular with sharp edges. To check it, 20 bricks are selected at random and they are stacked along the length, along the width and then along the height. For the standard bricks of size 190 mm × 90 mm × 90 mm. IS code permits the following limits:

Lengthwise:	3680	to	3920	mm
Widthwise:	1740	to	1860	mm
Heightwise:	1740	to	1860	mm.

The following *field tests* help in ascertaining the good quality bricks:

- (i) uniformity in size
- (ii) uniformity in colour
- (iii) structure
- (iv) hardness test
- (v) sound test
- (vi) strength test.

(i) **Uniformity in Size:** A good brick should have rectangular plane surface and uniform in size. This check is made in the field by observation.

(ii) **Uniformity in Colour:** A good brick will be having uniform colour throughout. This observation may be made before purchasing the brick.

(iii) **Structure:** A few bricks may be broken in the field and their cross-section observed. The section should be homogeneous, compact and free from defects such as holes and lumps.

(iv) **Sound Test:** If two bricks are struck with each other they should produce clear ringing sound. The sound should not be dull.

(v) **Hardness Test:** For this a simple field test is scratch the brick with nail. If no impression is marked on the surface, the brick is sufficiently hard

(vi) **Efflorescence:** The presence of alkalies in brick is not desirable because they form patches of gray powder by absorbing moisture. Hence to determine the presence of alkalies this test is performed as explained below:

Place the brick specimen in a glass dish containing water to a depth of 25 mm in a well ventilated room. After all the water is absorbed or evaporated again add water for a depth of 25 mm. After second evaporation observe the bricks for white/grey patches. The observation is reported as 'nil', 'slight', 'moderate', 'heavy' or serious to mean

- (a) Nil: No patches
- (b) Slight: 10% of area covered with deposits
- (c) Moderate: 10 to 50% area covered with deposit but unaccompanied by flaking of the surface.
- (d) Heavy: More than 50 per cent area covered with deposits but unaccompanied by flaking of the surface.
- (e) Serious: Heavy deposits of salt accompanied by flaking of the surface.

### 1.2.4 Classification of Bricks Based on their Quality

The bricks used in construction are classified as:

- (i) First class bricks
- (ii) Second class bricks
- (iii) Third class bricks and
- (iv) Fourth class bricks

(i) **First Class Bricks:** These bricks are of standard shape and size. They are burnt in kilns. They fulfill all desirable properties of bricks.

(ii) **Second Class Bricks:** These bricks are ground moulded and burnt in kilns. The edges may not be sharp and uniform. The surface may be somewhat rough. Such bricks are commonly used for the construction of walls which are going to be plastered.

(iii) **Third Class Bricks:** These bricks are ground moulded and burnt in clamps. Their edges are somewhat distorted. They produce dull sound when struck together. They are used for temporary and unimportant structures.

(iv) **Fourth Class Bricks:** These are the over burnt bricks. They are dark in colour. The shape is irregular. They are used as aggregates for concrete in foundations, floors and roads.

### 1.2.5 Uses of Bricks

Bricks are used in the following civil works:

- (i) As building blocks.
- (ii) For lining of ovens, furnaces and chimneys.
- (iii) For protecting steel columns from fire.
- (iv) As aggregates in providing water proofing to R.C.C. roofs.
- (v) For pavers for footpaths and cycle tracks.
- (vi) For lining sewer lines.

## 1.3 LIME

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It is an important binding material used in building construction. Lime has been used as the material of construction from ancient time. When it is mixed with sand it provides lime mortar and when mixed with sand and coarse aggregate, it forms lime concrete.

### 1.3.1 Types of Limes and their Properties

The limes are classified as fat lime, hydraulic lime and poor lime:

(i) **Fat lime:** It is composed of 95 percentage of calcium oxide. When water is added, it slakes vigorously and its volume increases to 2 to  $2\frac{1}{2}$  times. It is white in colour. Its properties are:

- (a) hardens slowly
- (b) has high degree of plasticity
- (c) sets slowly in the presence of air
- (d) white in colour
- (e) slakes vigorously.

(ii) **Hydraulic lime:** It contains clay and ferrous oxide. Depending upon the percentage of clay present, the hydraulic lime is divided into the following three types:

- (a) Feebly hydraulic lime (5 to 10% clay content)
- (b) Moderately hydraulic lime (11 to 20% clay content)
- (c) Eminently hydraulic lime (21 to 30% clay content)

The properties of hydraulic limes are:

- Sets under water
- Colour is not perfectly white
- Forms a thin paste with water and do not dissolve in water.
- Its binding property improves if its fine powder is mixed with sand and kept in the form of heap for a week, before using.

(iii) **Poor lime:** It contains more than 30% clay. Its colour is muddy. It has poor binding property. The mortar made with such lime is used for inferior works.

IS 712-1973 classifies lime as class A, B, C, D and E.

*Class A Lime:* It is predominantly hydraulic lime. It is normally supplied as hydrated lime and is commonly used for structural works.

*Class B Lime:* It contains both hydraulic lime and fat lime. It is supplied as hydrated lime or as quick lime. It is used for making mortar for masonry works.

*Class C Lime:* It is predominantly fat lime, supplied both as quick lime and fat lime. It is used for finishing coat in plastering and for white washing.

*Class D Lime:* This lime contains large quantity of magnesium oxide and is similar to fat lime. This is also commonly used for white washing and for finishing coat in plastering.

*Class E Lime:* It is an impure lime stone, known as kankar. It is available in modular and block form. It is supplied as hydrated lime. It is commonly used for masonry mortar.

### 1.3.2 Tests on Limestones

The following practical tests are made on limestones to determine their suitability:

- (i) Physical tests
- (ii) Heat test
- (iii) Chemical test
- (iv) Ball test.



(i) **Physical Test:** Pure limestone is white in colour. Hydraulic limestones are bluish grey, brown or are having dark colours. The hydraulic lime gives out earthy smell. They are having clayey taste. The presence of lumps give indication of quick lime and unburnt lime stones.

(ii) **Heat Test:** A piece of dry stone weighing  $W_1$  is heated in an open fire for few hours. If weight of sample after cooling is  $W_2$ , the loss of weight is  $W_2 - W_1$ . The loss of weight indicates the amount of carbon dioxide. From this the amount of calcium carbonate in limestone can be worked out.

(iii) **Chemical Test:** A teaspoon full of lime is placed in a test tube and dilute hydrochloric acid is poured in it. The content is stirred and the test tube is kept in the stand for 24 hours. Vigorous effervescence and less residue indicates pure limestone. If effervescence is less and residue is more it indicates impure limestone.

If thick gel is formed and after test tube is held upside down it is possible to identify class of lime as indicated below:

- Class A lime, if gel do not flow.
- Class B lime, if gel tends to flow down.
- Class C lime, if there is no gel formation.

(iv) **Ball Test:** This test is conducted to identify whether the lime belongs to class C or to class B. By adding sufficient water about 40 mm size lime balls are made and they are left undisturbed for six hours. Then the balls are placed in a basin of water. If within minutes slow expansion and slow disintegration starts it indicates class C lime. If there is little or no expansion, but only cracks appear it belongs to class B lime.

### 1.3.3 Uses of Lime

The following are the uses of lime in civil works:

- (i) For white washing.
- (ii) For making mortar for masonry works and plastering.
- (iii) To produce lime sand bricks.
- (iv) For soil stabilization.
- (v) As a refractory material for lining open hearth furnaces.
- (vi) For making cement.

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## 1.4 CEMENT

Cement is a commonly used binding material in the construction. The cement is obtained by burning a mixture of calcarious (calcium) and argillaceous (clay) material at a very high temperature and then grinding the clinker so produced to a fine powder. It was first produced by a mason Joseph Aspdin in England in 1824. He patented it as portland cement.

### 1.4.1 Types of Cement

In addition to ordinary portland cement there are many varieties of cement. Important varieties are briefly explained below:

(i) **White Cement:** The cement when made free from colouring oxides of iron, manganese and chlorine results into white cement. In the manufacture of this cement, the oil fuel is used instead of coal for burning. White cement is used for the floor finishes, plastering, ornamental works etc. In swimming pools white cement is used to replace glazed tiles. It is used for fixing marbles and glazed tiles.

(ii) **Coloured Cement:** The cements of desired colours are produced by intimately mixing pigments with ordinary cement. The chlorine oxide gives green colour. Cobalt produce blue colour. Iron oxide with different proportion produce brown, red or yellow colour. Addition of manganese dioxide gives black or brown coloured cement. These cements are used for giving finishing touches to floors, walls, window sills, roofs etc.

(iii) **Quick Setting Cement:** Quick setting cement is produced by reducing the percentage of gypsum and adding a small amount of aluminium sulphate during the manufacture of cement. Finer grinding also adds to quick setting property. This cement starts setting within 5 minutes after adding water and becomes hard mass within 30 minutes. This cement is used to lay concrete under static or slowly running water.

(iv) **Rapid Hardening Cement:** This cement can be produced by increasing lime content and burning at high temperature while manufacturing cement. Grinding to very fine is also necessary. Though the initial and final setting time of this cement is the same as that of portland cement, it gains strength in early days. This property helps in earlier removal of form works and speed in construction activity.

(v) **Low Heat Cement:** In mass concrete works like construction of dams, heat produced due to hydration of cement will not get dispersed easily. This may give rise to cracks. Hence in such constructions it is preferable to use low heat cement. This cement contains low percentage (5%) of tricalcium aluminate ( $C_3A$ ) and higher percentage (46%) of dicalcium silicate ( $C_2S$ ).

(vi) **Pozzulana Cement:** Pozzulana is a volcanic power found in Italy. It can be processed from shales and certain types of clay also. In this cement pozzulana material is 10 to 30 per cent. It can resist action of sulphate. It releases less heat during setting. It imparts higher degree of water tightness. Its tensile strength is high but compressive strength is low. It is used for mass concrete works. It is also used in sewage line works.

(vii) **Expanding Cement:** This cement expands as it sets. This property is achieved by adding expanding medium like sulpho aluminate and a stabilizing agent to ordinary cement. This is used for filling the cracks in concrete structures.

(viii) **High Alumina Cement:** It is manufactured by calcining a mixture of lime and bauxite. It is more resistant to sulphate and acid attack. It develops almost full strength within 24 hours of adding water. It is used for under water works.

(ix) **Blast Furnace Cement:** In the manufacture of pig iron, slag comes out as a waste product. By grinding clinkers of cement with about 60 to 65 per cent of slag, this cement is produced. The properties of this cement are more or less same as ordinary cement, but it is cheap, since it utilise waste product. This cement is durable but it gains the strength slowly and hence needs longer period of curing.

(x) **Acid Resistant Cement:** This cement is produced by adding acid resistant aggregated such as quartz, quartzite, sodium silicate or soluble glass. This cement has good resistance to action of acid and water. It is commonly used in the construction of chemical factories.

(xi) **Sulphate Resistant Cement:** By keeping the percentage of tricalcium aluminate  $C_3A$  below five per cent in ordinary cement this cement is produced. It is used in the construction of structures which are likely to be damaged by alkaline conditions. Examples of such structures are canals, culverts etc.

(xii) **Fly Ash Blended Cement:** Fly ash is a byproduct in thermal stations. The particles of fly ash are very minute and they fly in the air, creating air pollution problems. Thermal power stations have to spend lot of money to arrest fly ash and dispose safely. It is found that one of the best way to dispose fly ash is to mix it with cement in controlled condition and derive some of the beneficiary effects on cement. Now-a-days cement factories produce the fly ash in their own thermal stations or borrow it from other thermal stations and further process it to make it suitable to blend with cement. 20 to 30% fly ash is used for blending.

Fly ash blended cements have superior quality of resistance to weathering action. The ultimate strength gained is the same as that with ordinary portland cement. However strength gained in the initial stage is slow. Birla plus, Birla star, A.C.C. Suraksha are some of the brand name of blended cement.

#### 1.4.2 Properties of Ordinary Portland Cement

(i) **Chemical properties:** Portland cement consists of the following chemical compounds:

(a) Tricalcium silicate	$3 \text{ CaO} \cdot \text{SiO}_2$ ( $C_3S$ )	40%
(b) Dicalcium silicate	$2\text{CaO} \cdot \text{SiO}_2$ ( $C_2S$ )	30%
(c) Tricalcium aluminate	$3\text{CaO} \cdot \text{Al}_2\text{O}_3$ ( $C_3A$ )	11%
(d) Tetracalcium aluminate	$4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$ ( $C_3AF$ )	11%

There may be small quantities of impurities present such as calcium oxide (CaO) and magnesium oxide (MgO).

When water is added to cement,  $C_3A$  is the first to react and cause initial set. It generates great amount of heat.  $C_3S$  hydrates early and develops strength in the first 28 days. It also generates heat.  $C_2S$  is the next to hydrate. It hydrates slowly and is responsible for increase in ultimate strength.  $C_4AF$  is comparatively inactive compound.

(ii) **Physical properties:** The following physical properties should be checked before selecting a portland cement for the civil engineering works. IS 269–1967 specifies the method of testing and prescribes the limits:

(a) Fineness	(b) Setting time
(c) Soundness	(d) Crushing strength.

(a) **Fineness:** It is measured in terms of percentage of weight retained after sieving the cement through 90 micron sieve or by surface area of cement in square centimeters per gramme of cement. According to IS code specification weight retained on the sieve should not be more than 10 per cent. In terms of specific surface should not be less than  $2250 \text{ cm}^2/\text{gm}$ .

(b) **Setting time:** A period of 30 minutes as minimum setting time for initial setting and a maximum period of 600 minutes as maximum setting time is specified by IS code, provided the tests are conducted as per the procedure prescribed by IS 269-1967.

(c) **Soundness:** Once the concrete has hardened it is necessary to ensure that no volumetric changes takes place. The cement is said to be unsound, if it exhibits volumetric instability after hardening. IS code recommends test with Le Chatelier mould for testing this property. At the end of the test, the indicator of Le Chatelier mould should not expand by more than 10 mm.

(a) **Crushing strength:** For this mortar cubes are made with standard sand and tested in compression testing machine as per the specification of IS code. The minimum strength specified is 16 N/mm<sup>2</sup> after 3 days and 22 N/mm<sup>2</sup> after 7 days of curing.

### 1.4.3 Physical Tests on Cement

(a) **Soundness Test:** It is conducted by sieve analysis. 100 gms of cement is taken and sieved through IS sieve No. 9 for fifteen minutes. Residue on the sieve is weighed. This should not exceed 10 per cent by weight of sample taken.

(b) **Setting Time:** Initial setting time and final setting time are the two important physical properties of cement. Initial setting time is the time taken by the cement from adding of water to the starting of losing its plasticity. Final setting time is the time lapsed from adding of the water to complete loss of plasticity. Vicat apparatus is used for finding the setting times [Ref. Fig. 1.5]. Vicat apparatus consists of a movable rod to which any one of the three needles shown in figure can be attached. An indicator is attached to the movable rod. A vicat mould is associated with this apparatus which is in the form of split cylinder.

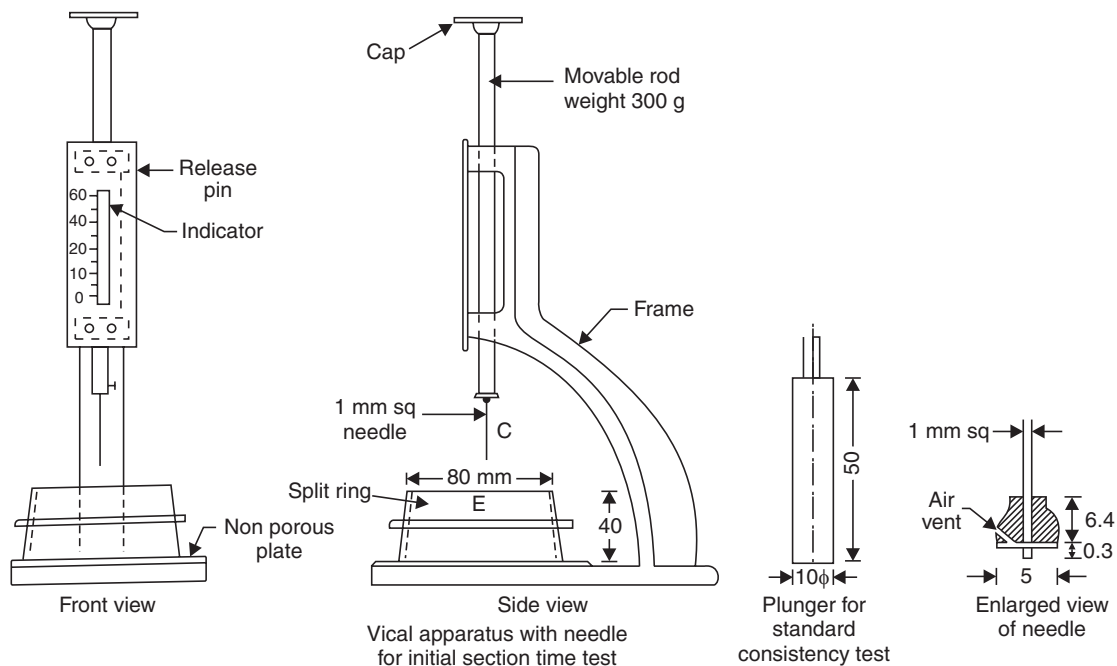


Fig. 1.5. Vicat apparatus

Before finding initial and final setting time it is necessary to determine water to be added to get standard consistency. For this 300 gms of cement is mixed with about 30% water and cement paste prepared is filled in the mould which rests on non porous plate. The plunger is attached to the movable rod of vicat apparatus and gently lowered to touch the paste in the mould. Then the plunger is allowed to move freely. If the penetration is 5 mm to 7 mm from the bottom of the mould, then cement is having standard consistency. If not, experiment is repeated with different proportion of water fill water required for standard consistency is found. Then the tests for initial and final setting times can be carried out as explained below:

*Initial Setting Time:* 300 gms of cement is thoroughly mixed with 0.85 times the water for standard consistency and vicat mould is completely filled and top surface is levelled. 1 mm square needle is fixed to the rod and gently placed over the paste. Then it is freely allowed to penetrate. In the beginning the needle penetrates the paste completely. As time lapses the paste start losing its plasticity and offers resistance to penetration. When needle can penetrate up to 5 to 7 mm above bottom of the paste experiment is stopped and time lapsed between the addition of water and end if the experiment is noted as initial setting time.

*Final Setting Time.* The square needle is replaced with annular collar. Experiment is continued by allowing this needle to freely move after gently touching the surface of the paste. Time lapsed between the addition of water and the mark of needle but not of annular ring is found on the paste. This time is noted as final setting time.

(c) **Soundness Test:** This test is conducted to find free lime in cement, which is not desirable. Le Chatelier apparatus shown in Fig. 1.6 is used for conducting this test. It consists of a split brass mould of diameter 30 mm and height 30 mm. On either side of the split, there are two indicators, with pointed ends. The ends of indicators are 165 mm from the centre of the mould.

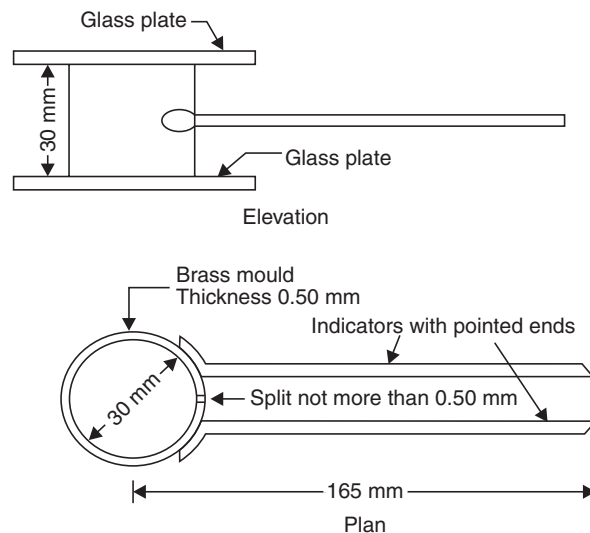


Fig. 1.6. Le Chatelier's apparatus

Properly oiled Le Chatelier mould is placed on a glass plate and is filled completely with a cement paste having 0.78 times the water required for standard consistency. It is then covered with

another glass plate and a small weight is placed over it. Then the whole assembly is kept under water for 24 hours. The temperature of water should be between 24°C and 50°C. Note the distance between the indicator. Then place the mould again in the water and heat the assembly such that water reaches the boiling point in 30 minutes. Boil the water for one hour. The mould is removed from water and allowed to cool. The distance between the two pointers is measured. The difference between the two readings indicate the expansion of the cement due to the presence of unburnt lime. This value should not exceed 10 mm.

(d) **Crushing Strength Test:** For this 200 gm of cement is mixed with 600 gm of standard sand conforming to IS 650–1966. After mixing thoroughly in dry condition for a minute distilled potable water  $\frac{P}{4} + 3$  percentage is added where P is the water required for the standard consistency. They are mixed with trowel for 3 to 4 minutes to get uniform mixture. The mix is placed in a cube mould of 70.6 mm size (Area 5000 mm<sup>2</sup>) kept on a steel plate and prodded with 25 mm standard steel rod 20 times within 8 seconds. Then the mould is placed on a standard vibrating table that vibrates at a speed of 12000 ± 400 vibration per minute. A hopper is secured at the top and the remaining mortar is filled. The mould is vibrated for two minutes and hopper removed. The top is finished with a knife or with a trowel and levelled. After 24 ± 1 hour mould is removed and cube is placed under clean water for curing.

After specified period cubes are tested in compression testing machine, keeping the specimen on its level edges. Average of three cubes is reported as crushing strength. The compressive strength at the end of 3 days should not be less than 11.5 N/mm<sup>2</sup> and that at the end of 7 days not less than 17.5 N/mm<sup>2</sup>.

#### 1.4.4 Uses of Cement

Cement is used widely for the construction of various structures. Some of them are listed below:

- (i) Cement slurry is used for filling cracks in concrete structures.
- (ii) Cement mortar is used for masonry work, plastering and pointing.
- (iii) Cement concrete is used for the construction of various structures like buildings, bridges, water tanks, tunnels, docks, harbours etc.
- (iv) Cement is used to manufacture lamp posts, telephone posts, railway sleepers, piles etc.
- (v) For manufacturing cement pipes, garden seats, dust bins, flower pots etc. cement is commonly used.
- (vi) It is useful for the construction of roads, footpaths, courts for various sports etc.

## 1.5 TIMBER

Timber refers to wood used for construction works. In fact the word *timber* is derived from an old English word 'Timbrian' which means 'to build'. A tree that yields good wood for construction is called '*Standing Timber*.' After felling a tree, its branches are cut and its stem is roughly converted into pieces of suitable length, so that it can be transported to timber yard. This form of timber is known as *rough timber*. By sawing, rough timber is converted into various commercial sizes like planks, battens, posts, beams etc. Such form of timber is known as *converted timber*.

Timber was used as building material even by primitive man. Many ancient temples, palaces and bridges built with timber can be seen even today.

### 1.5.1 Classification of Timber

Various bases are considered for the classification of timbers. The following are the important basis:

- (i) Mode of growth
- (ii) Modulus of elasticity
- (iii) Durability
- (iv) Grading
- (v) Availability.

(i) **Classification Based on Mode of Growth:** On the basis of mode of growth trees are classified as (a) Exogeneous and (b) Endogeneous

(a) **Exogeneous Trees:** These trees grow outward by adding distinct consecutive ring every year. These rings are known as annual rings. Hence it is possible to find the age of timber by counting these annual rings. These trees may be further divided into (1) coniferous and (2) deciduous.

*Coniferous trees* are having cone shaped leaves and fruits. The leaves do not fall till new ones are grown. They yield soft wood.

*Deciduous trees* are having broad leaves. These leaves fall in autumn and new ones appear in springs. They yield strong wood and hence they are commonly used in building construction.

The classification as *soft wood* and *hard wood* have commercial importance. The difference between soft wood and hard wood is given below:

1. In soft wood *annual rings* are seen distinctly whereas in hard wood they are indistinct.
2. The *colour* of soft wood is light whereas the colour of hard wood is dark.
3. Soft woods have lesser *strength* in compression and shear compared to hard woods.
4. Soft woods are *light* and hard woods are heavy.
5. *Fire resistance* of soft wood is poor compared to that of hard wood.
6. The *structure* of soft wood is resinous while structure of hard wood is close grained.

The cross-section of a exogeneous tree is as shown in the Fig. 1.7. The following components are visible to the naked eye:

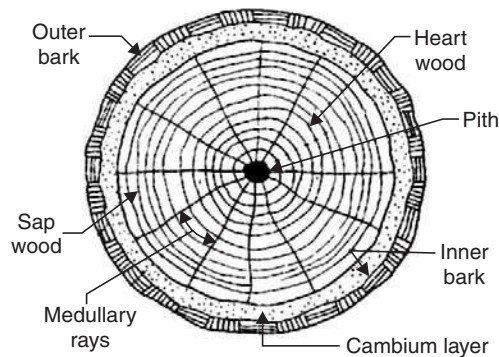


Fig. 1.7. Cross-section of exogeneous tree



1. *Pith*: It is the inner most part of the tree and hence the oldest part of exogeneous tree when the plant becomes old, the pith dies and becomes fibrous and dark. It varies in size and shape.

2. *Heart Wood*: This is the portion surrounding pith. It is dark in colour and strong. This portion is useful for various engineering purpose. This is the dead part of wood. It consists of several annular rings.

3. *Sap Wood*: It is the layer next to heart wood. It denotes recent growth and contains sap. It takes active part in the growth of trees by allowing sap to move in upward direction. The annual rings of sap wood are less sharply divided and are light in colour. The sap wood is also known as alburnum.

4. *Cambium Layer*: It is a thin layer of fresh sap lying between sap wood and the inner bark. It contains sap which is not yet converted into sap wood. If the bark is removed and cambium layer is exposed to atmosphere, cells cease to be active and tree dies.

5. *Inner Bark*: It is a inner skin of tree protecting the cambium layer. It gives protection to cambium layer.

6. *Outer Bark*: It is the outer skin of the tree and consists of wood fibres. Sometimes it contains fissures and cracks.

7. *Medullary Rags*: These are thin radial fibres extending from pith to cambium layer. They hold annular rings together. In some of trees they are broken and some other they may not be prominent.

(b) *Endogeneous Trees*: These trees grow inwards. Fresh fibrous mass is in the inner most portion. Examples of endogenous trees are bamboo and cane. They are not useful for structural works.

(ii) **Classification Based on Modulus of Elasticity**: Young's modulus is determined by conducting bending test. On this basis timber is classified as:

Group A:  $E = 12.5 \text{ kN/mm}^2$

Group B:  $E = 9.8 \text{ kN/mm}^2$  to  $12.5 \text{ kN/mm}^2$

Group C:  $E = 5.6 \text{ kN/mm}^2$  to  $9.8 \text{ kN/mm}^2$ .

(iii) **Classification Based on Durability**: Durability tests are conducted by the forest research establishment. They bury test specimen of size  $600 \times 50 \times 50 \text{ mm}$  in the ground to half their length and observe their conditions regularly over several years. Then timbers are classified as:

High durability: If average life is more than 10 years.

Moderate durability: Average life between 5 to 10 years.

Low durability: Average life less than 5 years.

(iv) **Classification Based on Grading**: IS 883-1970 classifies the structural timber into three grades-select grade, grade I and grade II. The classification is based on permissible stresses, defects etc.

(v) **Classification Based on Availability**: Forest departments classify timbers based on the availability as

X—Most common.  $1415 \text{ m}^3$  or more per year

Y—Common.  $355 \text{ m}^3$  to  $1415 \text{ m}^3$  per year

Z—Less common. Less than  $355 \text{ m}^3$  per year.



### 1.5.2 Properties of Timber

Properties of good timbers are:

*Colour:* It should be uniform.

*Odour:* It should be pleasant when cut freshly.

*Soundness:* A clear ringing sound when struck indicates the timber is good.

*Texture:* Texture of good timber is fine and even.

*Grains:* In good timber grains are close.

*Density:* Higher the density stronger is the timber.

*Hardness:* Harder timbers are strong and durable.

*Warping:* Good timber do not warp under changing environmental conditions.

*Toughness:* Timber should be capable of resisting shock loads.

*Abrasion:* Good timber do not deteriorate due to wear. This property should be looked into, if timber is to be used for flooring.

*Strength:* Timber should have high strength in bending, shear and direct compression.

*Modulus of Elasticity:* Timber with higher modulus of elasticity are preferred in construction.

*Fire resistance:* A good timber should have high resistance to fire.

*Permeability:* Good timber has low water permeability.

*Workability:* Timber should be easily workable. It should not clog the saw.

*Durability:* Good timber is one which is capable of resisting the action of fungi and insects attack

*Defects:* Good timber is free from defects like dead knots, shakes and cracks.

### 1.5.3 Seasoning of Timber

This is a process by which moisture content in a freshly cut tree is reduced to a suitable level. By doing so the durability of timber is increased. The various methods of seasoning used may be classified into:

(i) Natural seasoning

(ii) Artificial seasoning.

(i) **Natural Seasoning:** It may be air seasoning or water seasoning. *Air seasoning* is carried out in a shed with a platform. On about 300 mm high platform timber balks are stacked as shown in Fig. 1.8. Care is taken to see that there is proper air circulation around each timber balk. Over a period, in a natural process moisture content reduces. A well seasoned timber contains only 15% moisture. This is a slow but a good process of seasoning.

*Water seasoning* is carried out on the banks of rivers. The thicker end of the timber is kept pointing upstream side. After a period of 2 to 4 weeks the timber is taken out. During this period sap contained in the timber is washed out to a great extent. Then timber is staked in a shed with free air circulation.

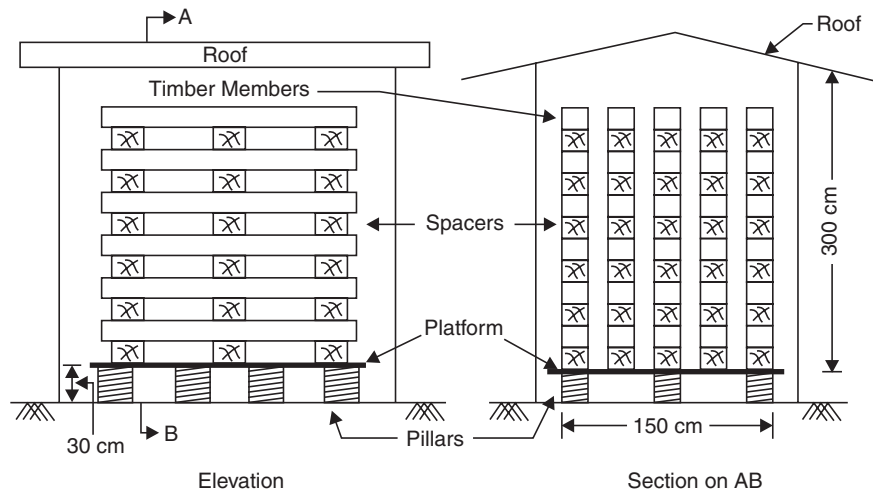


Fig. 1.8. Air seasoning

(ii) **Artificial Seasoning:** In this method timber is seasoned in a chamber with regulated heat, controlled humidity and proper air circulation. Seasoning can be completed in 4 to 5 days only. The different methods of seasoning are:

- (a) Boiling
- (b) Kiln seasoning
- (c) Chemical seasoning
- (d) Electrical seasoning.

(a) **Boiling:** In this method timber is immersed in water and then water is boiled for 3 to 4 hours. Then it is dried slowly. Instead of boiling water hot steam may be circulated on timber. The process of seasoning is fast, but costly.

(b) **Kiln Seasoning:** Kiln is an airtight chamber. Timber to be seasoned is placed inside it. Then fully saturated air with a temperature  $35^{\circ}\text{C}$  to  $38^{\circ}\text{C}$  is forced in the kiln. The heat gradually reaches inside timber. Then relative humidity is gradually reduced and temperature is increased, and maintained till desired degree of moisture content is achieved.

The kiln used may be stationary or progressive. In progressive kiln the carriages carrying timber travel from one end of kiln to other end gradually. The hot air is supplied from the discharging end so that temperature increase is gradual from charging end to discharging end. This method is used for seasoning on a larger scale.

(c) **Chemical Seasoning:** In this method, the timber is immersed in a solution of suitable salt. Then the timber is dried in a kiln. The preliminary treatment by chemical seasoning ensures uniform seasoning of outer and inner parts of timber.

(d) **Electrical Seasoning:** In this method high frequency alternate electric current is passed through timber. Resistance to electric current is low when moisture content in timber is high. As moisture content reduces the resistance reduces. Measure of resistance can be used to stop seasoning at appropriate level.

However it is costly process. This technique has been tried in some plywood industries but not in seasoning of timber on mass scale.

### 1.5.4 Defects in Timber

Various defects which are likely to occur in timber may be grouped into the following three:

- (i) Due to natural forces
- (ii) Due to defective seasoning and conversions.
- (iii) Due to attack by fungi and insects.

(i) **Defects due to Natural Forces:** The following defects are caused by natural forces:

- (a) Knots
- (b) Shakes
- (c) Wind cracks
- (d) Upsets

(a) **Knots:** When a tree grows, many of its branches fall and the stump of these branches in the trunk is covered. In the sawn pieces of timber the stump of fallen branches appear as knots. Knots are dark and hard pieces. Grains are distorted in this portion. Figure 1.9 shows some varieties of knots. If the knot is intact with surrounding wood, it is called live knot. If it is not held firmly it is dead knot.

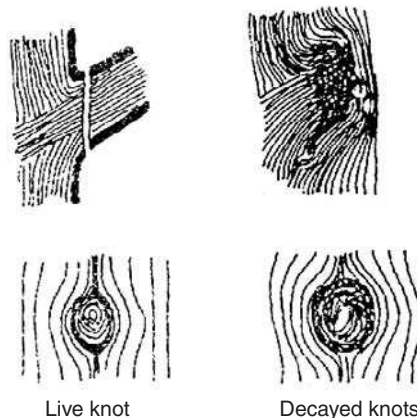


Fig. 1.9. Knots

(b) **Shakes:** The shakes are cracks in the timber which appear due to excessive heat, frost or twisting due to wind during the growth of a tree. Depending upon the shape and the positions shakes can be classified as star shake, cup shake, ring shakes and heart shakes [Ref. Fig. 1.10]

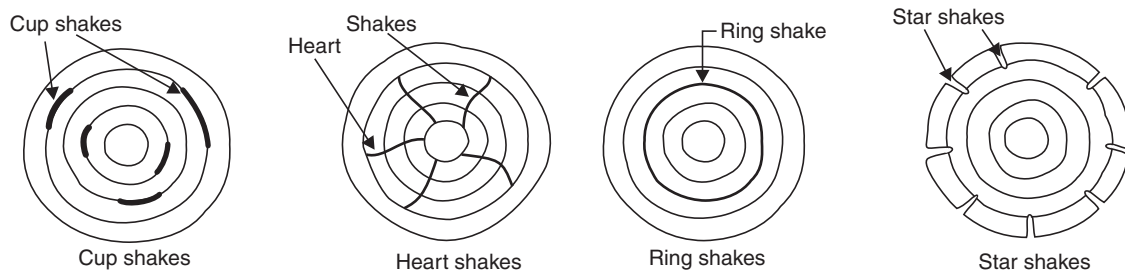


Fig. 1.10. Shakes

(c) **Wind Cracks:** These are the cracks on the outside of a log due to the shrinkage of the exterior surface. They appear as shown in Fig. 1.11.

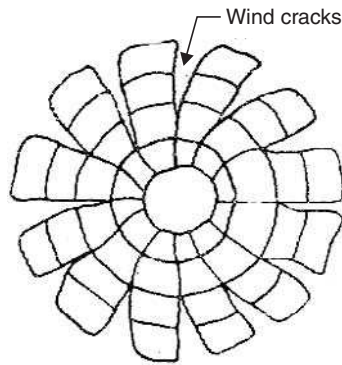


Fig. 1.11. Wind cracks

(d) **Upsets:** Figure 1.12 shows a typical upset in a timber. This type of defect is due to excessive compression in the tree when it was young. Upset is an injury by crushing. This is also known as rupture.

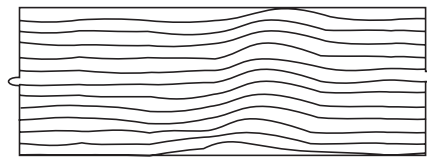


Fig. 1.12. Upset

(ii) **Defects due to Defective Seasoning and Conversion:** If seasoning is not uniform, the converted timber may warp and twist in various directions. Sometimes honey combining and even cracks appear. This type of defects are more susceptible in case of kiln seasoning.

In the process of converting timber to commercial sizes and shapes the following types of defects are likely to arise: chip marks, torn grain etc.

(iii) **Defects due to Fungi and Insects Attack:** Fungi are minute microscopic plant organism. They grow in wood if moisture content is more than 20°C and exposed to air. Due to fungi attack rotting of wood, takes place. Wood becomes weak and stains appear on it.

Beetles, marine borers and termites (white ants) are the insects which eat wood and weaken the timber. Some woods like teak have chemicals in their compositions and resist such attacks. Other woods are to be protected by chemical treatment.

### 1.5.5 Preservation of Timber

Preservation of timber means protecting timber from fungi and insects attack so that its life is increased. Timber is to be seasoned well before application of preservatives. The following are the widely used preservatives:

1. Tar
2. Paints

3. Chemical salt
4. Creosote
5. ASCO

1. **Tar:** Hot coal tar is applied to timber with brush. The coating of tar protects the timber from the attack of fungi and insects. It is a cheapest way of protecting timber. Main disadvantage of this method of preservation is that appearance is not good after tar is applied it is not possible to apply other attractive paints. Hence tarring is made only for the unimportant structures like fence poles.

2. **Paints:** Two to three coats of oil paints are applied on clean surface of wood. The paint protects the timber from moisture. The paint is to be applied from time to time. Paint improves the appearance of the timber. Solignum paint is a special paint which protects the timber from the attack of termites.

3. **Chemical salt:** These are the preservatives made by dissolving salts in water. The salts used are copper sulphate, masonry chloride, zinc chloride and sodium fluoride. After treating the timber with these chemical salt paints and varnishes can be applied to get good appearance.

4. **Creosote:** Creosote oil is obtained by distillation of coal tar. The seasoned timber is kept in an air tight chamber and air is exhausted. Then creosote oil is pumped into the chamber at a pressure of 0.8 to 1.0 N/mm<sup>2</sup> at a temperature of 50°C. After 1 to 2 hours timber is taken out of the chamber.

5. **ASCO:** This preservative is developed by the Forest Research Institute, Dehradun. It consists of 1 part by weight of hydrated arsenic pentoxide ( $As_2O_5 \cdot 2H_2O$ ), 3 parts by weight of copper sulphate ( $CuSO_4 \cdot 5H_2O$ ) and 4 parts by weight of potassium dichromate ( $K_2Cr_2O_7$ ) or sodium dichromate ( $Na_2Cr_2O_7 \cdot 2H_2O$ ). This preservative is available in powder form. By mixing six parts of this powder with 100 parts of water, the solution is prepared. The solution is then sprayed over the surface of timber. This treatment prevents attack from termites. The surface may be painted to get desired appearance.

### 1.5.6 Uses of Timber

Timber is used for the following works:

1. For heavy construction works like columns, trusses, piles.
2. For light construction works like doors, windows, flooring and roofing.
3. For other permanent works like for railway sleepers, fencing poles, electric poles and gates.
4. For temporary works in construction like scaffolding, centering, shoring and strutting, packing of materials.
5. For decorative works like showcases and furnitures.
6. For body works of buses, lorries, trains and boats
7. For industrial uses like pulps (used in making papers), card boards, wall papers
8. For making sports goods and musical instruments.

**QUESTIONS**

1. Discuss the geological classification of stones.
2. Briefly explain physical and chemical classification of rocks.
3. Discuss the characteristics of good building stones.
4. Explain any three tests performed on stones to find their properties.
5. Write various uses of stones in civil engineering works.
6. Name any four stones along with their characteristics and uses.
7. What do you understand by the term brick? Explain different types of bricks.
8. Describe the properties of good bricks.
9. Explain briefly any four types of tests conducted on bricks in the laboratories to ascertain their qualities.
10. What are the field tests carried out to determine the qualities of the brick?
11. Explain classification of bricks based on their quality.
12. What are the different uses of bricks?
13. Differentiate between fat lime and hydraulic lime.
14. Briefly explain IS code classification of lime as class A, B, C, D and E.
15. What are the test carried on lime? Briefly explain.
16. List the various uses of lime.
17. What is cement? How quick setting and rapid hardening cement differs from portland cement?
18. Write short notes on
  - (i) Low heat cement
  - (ii) Pozzulana cement
  - (iii) Coloured cement and
  - (iv) Expanding cement.
19. State chemical and physical properties of portland cement.
20. What is standard consistency of cement? How it is determined in the laboratory?
21. Explain the terms initial setting time and final setting time of cement. How they are determined?
22. Explain the following test procedure on cement:
  - (i) Soundness test
  - (ii) Crushing strength test
23. List various uses of cement.
24. Explain the terms: timber, standing timber, rough timber and converted timber.
25. Draw and explain cross-section of an exogeneous tree.

- 26.** Differentiate between
  - (i) exogeneous and endogeneous trees
  - (ii) soft wood and hard wood.
- 27.** What are the requirements of good timber?
- 28.** What is meant by seasoning of timber? Distinguish between natural and artificial seasoning.
- 29.** Write short notes on:
  - (i) Air seasoning
  - (ii) Water seasoning
  - (iii) Kiln seasoning and
  - (iv) Chemical seasoning.
- 30.** Explain various defects in timber due to natural forces.
- 31.** Write short notes on defects in timber due to
  - (i) defective seasoning and conversion
  - (ii) attack by fungi and insects.
- 32.** What do you understand by the term preservation of timber? Briefly explain the different methods of preservation adopted.
- 33.** State different uses of timber.

# Mortars

Mortar is an intimate mixture of binding material, fine aggregate and water. When water is added to the dry mixture of binding material and the inert material, binding material develops the property that binds not only the inert material but also the surrounding stones and bricks. If the cement is the binding material, then the mortar is known as cement mortar. Other mortars commonly used are lime mortar and mud mortar. The inert material used is sand. In this chapter, first an introduction is given to the inert material sand and then the proportioning, mixing, curing, properties and uses of different mortars is explained. At the end of the chapter various tests conducted on mortars is presented.

## 2.1 SAND

Sand is a natural product which is obtained as river sand, nalla sand and pit sand. However sea sand should not be used for the following reasons:

1. It contains salt and hence structure will remain damp. The mortar is affected by efflorescence and blisters appear.
2. It contains shells and other organic matter, which decompose after some time, reducing the life of the mortar.

Sand may be obtained artificially by crushing hard stones. Usually artificial sand is obtained as a by-product while crushing stones to get jelly (coarse aggregate).

Sand is used in mortar and concrete for the following purpose:

1. It sub-divides the paste of binding material into thin films and allows it to adhere and spread.
2. It fills up the gap between the building blocks and spreads the binding material.
3. It adds to the density of the mortar.
4. It prevents the shrinkage of the cementing material.
5. It allows carbon dioxide from the atmosphere to reach some depth and thereby improve setting power.
6. The cost of cementing material per unit volume is reduced as this low cost material increases the volume of mortar.



7. Silica of sand contributes to formation of silicates resulting into the hardened mass.

The properties of good sand are:

1. It should be chemically inert.
2. It should be free from organic or vegetable matter.
3. It should be free from salt.
4. It should contain sharp, angular and coarse grains.
5. It should be well graded.
6. It should be hard.

## 2.2 CEMENT MORTAR

For preparing mortar, first a mixture of cement and sand is made thoroughly mixing them in dry condition. Water is gradually added and mixed with shovels. The cement to sand proportion recommended for various works is as shown in Table 2.1

**Table 2.1.** Cement to sand proportions for various works

<i>S. No.</i>	<i>Works</i>	<i>Cement: Sand</i>
1	Masonry works	1:6 to 1:8
2	Plastering masonry	1:3 to 1:4
3	Plastering concrete	1:3
4	Pointing	1:2 to 1:3

**Curing:** Cement gains the strength gradually with hydration. Hence it is necessary to see that mortar is wet till hydration has taken place. The process to ensure sufficient moisture for hydration after laying mortar/concrete is called curing. Curing is ensured by spraying water. Curing normally starts 6–24 hours after mortar is used. It may be noted that in the initial period water requirement is more for hydration and gradually it reduces. Curing is recommended for 28 days.

**Properties of Cement Mortar:** The following are the important properties of cement mortar:

1. When water is added to the dry mixture of cement and sand, hydration of cement starts and it binds sand particles and also the surrounding surfaces of masonry and concrete.
2. A mix richer than 1:3 is prone to shrinkage.
3. Well proportioned mortar provides impervious surface.
4. Leaner mix is not capable of closing the voids in sand and hence the plastered surface is porous.
5. The strength of mortar depends upon the proportion of cement and sand. Strengths obtained with various proportion of cement and sand is shown in Table 2.2.

Table 2.2

S. No.	Cement: Sand	Compressive Strength
1	1:3	10 N/mm <sup>2</sup>
2	1:4	7.5 N/mm <sup>2</sup>
3	1:5	5.0 N/mm <sup>2</sup>
4	1:6	3.0 N/mm <sup>2</sup>
5	1:8	0.7 N/mm <sup>2</sup>

### Uses of Cement Mortar

Mortar is used

1. to bind masonry units like stone, bricks, cement blocks.
2. to plaster slab and walls make them impervious.
3. to give neat finishing to walls and concrete works.
4. for pointing masonry joints.
5. for preparing building blocks.
6. as a filler material in ferro cement works.
7. to fill joints and cracks in walls.
8. as a filler material in stone masonry.

## 2.3 LIME MORTAR

Fat lime and hydraulic limes are used for making lime mortar. If fat lime is used sand mixed is normally 2 to 3 times its volume. If hydraulic lime is used sand mixed is only 2 times the volume of lime. Lime is prepared by pounding, if quantity required is small or by grinding, if the required quantity is more.

**Pounding:** For pounding pits are formed in hard grounds. The size of pit is usually 1.80 m long, 0.4 m wide and 0.5 m deep. It is provided with lining of bricks or stones. Lime and sand dry mixed with required proportion is placed in the pit. Small quantity of water is added at intervals. In each interval the mix is pounded with wooden pounders and mortar is turned up and down. The process is continued till uniform colour and desired consistency is achieved.

**Grinding:** This is the better way of getting good mix. The grinding may be carried out in bullock driven grinding mill or in power driven grinding mill.

Figure 2.1 shows a typical bullock driven grinding mill. It consists of a circular trench of radius 3 to 4.5 m, 0.3 m wide and 0.4 m deep. A wooden shaft pivoted at centre carries a stone wheel of width just 50 mm to 100 mm less than that of trench. Bullock drive this wheel in the trench for grinding mortar. The dry mix is placed in the trench. Water is added gradually and bullock driven stone wheels grind the mix. A worker turns the mix up and down regularly. This method of preparing mortar needs 6 hours and can produce about 1.7 m<sup>3</sup> of mortar.

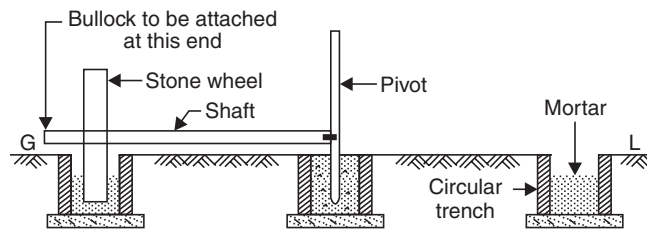


Fig. 2.1. Bullock driven grinding mill

Figure 2.2 shows a typical power driven grinding mill used for preparing lime mortar. Two rollers rotate in a pan of diameter 1.8 to 2.4 m. Either pan or roller is rotated with the help of oil engine or electric power. During mixing required quantity of water is added gradually.

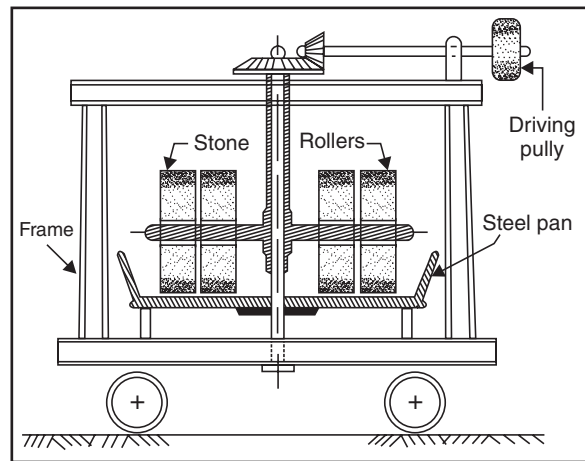


Fig. 2.2. Power driven grinding mill

Lime mortar is also having good grinding property. Fat lime mortar is used for plastering while hydraulic lime mortar is used for masonry construction. This mortar was considered cheap in olden days and was commonly used in small towns. However the cumbersome process of preparation and ease in availability of cement in market has almost replaced the use of lime mortar.

## 2.4 MUD MORTAR

Clay lumps are collected and are wetted with water and allowed to mature for 1 or 2 days. It is kneaded well until it attains required consistency. Sometimes fibrous materials like gobber is added in the mix. It prevents cracks in the plaster. If plaster is to be used for outer walls, it is sprayed or painted with bitumen.

It is cheap mortar. Its durability is less. It is normally used for the construction of temporary sheds and cheap houses in rural areas.

## 2.5 SPECIAL MORTAR

The following are some of the special mortars:

1. Cement clay mortar
2. Gauged mortar
3. Decorative mortar.

1. **Cement Clay Mortar:** Quality of clay mortar can be improved by adding cement to the mix. Normal proportion of clay to cement is 1:1. It maintains the economy to some extent and there is sufficient improvements in the durability of mud-mortar.

2. **Gauged Mortar:** It is the mortar obtained by adding cement to lime mortar. The usual proportion of cement, lime and sand are 1:1:6, 1:2:9 and 1:3:12. This mortar is to be used within half an hour after mixing cement. Obviously, it is cheaper than cement mortar and its quality is between that of cement mortar and lime mortar.

3. **Decorative Mortar:** These mortars are obtained by using coloured cement. They are used to give pleasant appearance to outer walls.

## 2.6 TESTS ON MORTAR

The following tests are conducted on the prepared mortars to ensure their quality:

1. Crushing Test
2. Tensile Strength Test
3. Adhesive Test.

1. **Crushing Test:** This test is carried out on a brick work with the mortar. This brick work is crushed in a compression testing machine and the load is noted down. Then the crushing strength is obtained as load divided by cross-sectional area.

2. **Tensile Strength Test:** The mortar prepared is placed in a mould of bricket which has central cross-sectional area as 38 mm × 38 mm. After curing the briquette [Fig. 2.3] is pulled under the grips of tensile testing machine. The ultimate load noted. Then the tensile strength of mortar is load divided by the central cross-sectional area.

3. **Adhesive Test:** Two bricks are joined together with mortar to be tested as shown in Fig. 2.4. The upper brick is suspended from an overhead support. A board is hung from the lower brick. Then weights are added to the board till the bricks separate. The adhesive strength is the load divided by area of contact.

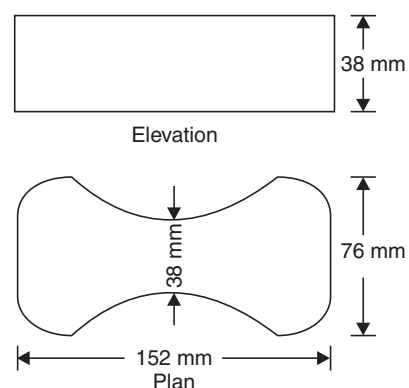


Fig. 2.3. Briquette for tensile test

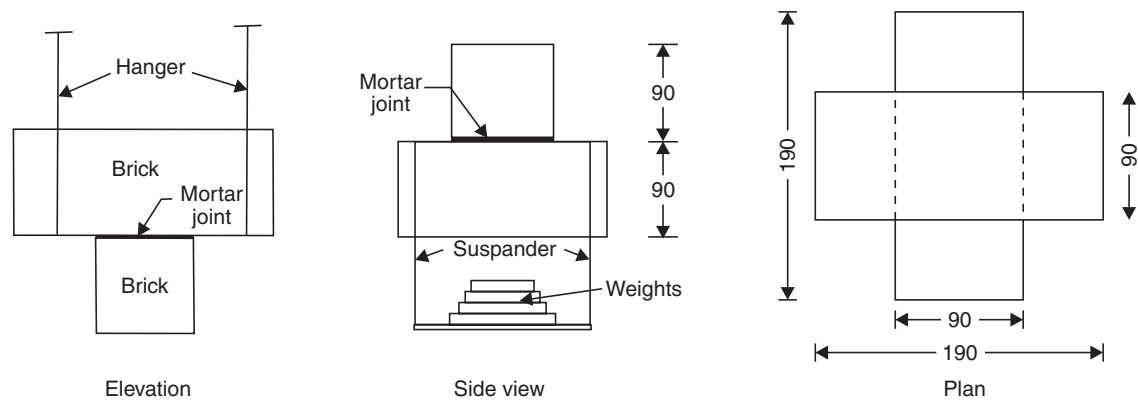


Fig. 2.4. Adhesiveness test arrangement

## QUESTIONS

1. Why sea sand should not be used for making mortar?
2. What are the different types of sand used in making mortar?
3. Why sand is used in mortars?
4. List the properties of good sand.
5. What proportion of cement to sand do you recommend for the following works?
  - (a) Masonry works
  - (b) Plastering masonry
  - (c) Plastering concrete surface
  - (d) Pointing.
6. State the important properties of cement mortar.
7. Where do you use cement mortar?
8. Explain with sketches the methods of grinding lime mortar.
9. Write short notes on mud mortar.
10. Briefly explain tests conducted on mortar.

## Concrete

Plain concrete, commonly known as concrete, is an intimate mixture of binding material, fine aggregate, coarse aggregate and water. This can be easily moulded to desired shape and size before it loses plasticity and hardens. Plain concrete is strong in compression but very weak in tension. The tensile property is introduced in concrete by inducing different materials and this attempt has given rise to RCC, RBC, PSC, FRC, cellular concrete and Ferro cement. In this chapter proportioning, mixing, curing, properties, tests and uses of plain concrete is dealt in detail. The other improved versions of concrete are explained and their special properties and uses are pointed out.

### 3.1 PLAIN CONCRETE

Major ingredients of concrete are:

1. Binding material (like cement, lime, polymer)
2. Fine aggregate (sand)
3. Coarse aggregates (crushed stone, jelly)
4. Water.

A small quantity of admixtures like air entraining agents, water proofing agents, workability agents etc. may also be added to impart special properties to the plain concrete mixture.

Depending upon the **proportion of ingredient**, strength of concrete varies. It is possible to determine the proportion of the ingredients for a particular strength by mix design procedure. In the absence of mix design the ingredients are proportioned as 1:1:2,  $1:1\frac{1}{2}:3$ , 1:2:4, 1:3:6 and 1:4:8, which is the ratio of weights of cement to sand to coarse aggregate.

In proportioning of concrete it is kept in mind that voids in coarse aggregates are filled with sand and the voids in sand are filled with cement paste. Proportion of ingredients usually adopted for various works are shown in Table 3.1.

**Table 3.1.** Proportion of cement, sand and coarse aggregates in concrete

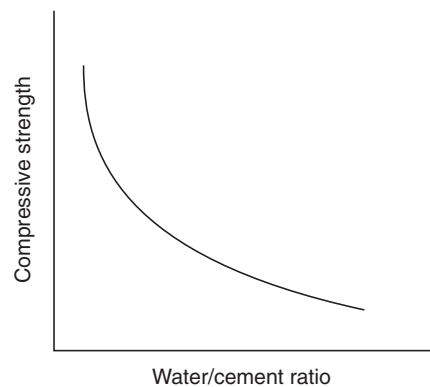
S. No.	Proportion	Nature of Work
1	1:1:2	For machine foundation, footings for steel columns and concreting under water.
2	$1:1\frac{1}{2}:3$	Water tanks, shells and folded plates, for other water retaining structures.
3	1:2:4	Commonly used for reinforced concrete works like beams, slabs, tunnel lining, bridges
4	1:3:6	Piers, abutments, concrete walls, sill of windows, floors.
5	1:4:8	Mass concretes like dam, foundation course for walls, for making concrete blocks.

### Functions of Various Ingredients

**Cement** is the binding material. After addition of water it hydrates and binds aggregates and the surrounding surfaces like stone and bricks. Generally richer mix (with more cement) gives more strength. Setting time starts after 30 minutes and ends after 6 hours. Hence concrete should be laid in its mould before 30 minutes of mixing of water and should not be subjected to any external forces till final setting takes place.

**Coarse aggregate** consists of crushed stones. It should be well graded and the stones should be of igneous origin. They should be clean, sharp, angular and hard. They give mass to the concrete and prevent shrinkage of cement. **Fine aggregate** consists of river sand. It prevents shrinkage of cement. When surrounded by cement it gains mobility enters the voids in coarse aggregates and binding of ingredients takes place. It adds density to concrete, since it fills the voids. Denser the concrete higher is its strength.

**Water** used for making concrete should be clean. It activates the hydration of cement and forms plastic mass. As it sets completely concrete becomes hard mass. Water gives workability to concrete which means water makes it possible to mix the concrete with ease and place it in final position. More the water better is the workability. However excess water reduces the strength of concrete. Figure 3.1 shows the variation of strength of concrete with water cement ratio. To achieve required workability and at the same time good strength a water cement ratio of 0.4 to 0.45 is used, in case of machine mixing and water cement ratio of 0.5 to 0.6 is used for hand mixing.

**Fig. 3.1.** Variation of strength of concrete with w/c ratio

## Preparing and Placing of Concrete

The following steps are involved in the concreting:

1. Batching
2. Mixing
3. Transporting and placing and
4. Compacting.

1. **Batching:** The measurement of materials for making concrete is known as batching. The following two methods of batching is practiced:

- (a) Volume batching
- (b) Weight batching.

(a) **Volume Batching:** In this method cement, sand and concrete are batched by volume. A gauge box is made with wooden plates, its volume being equal to that of one bag of cement. One bag of cement has volume of 35 litres. The required amount of sand and coarse aggregate is added by measuring on to the gauge box. The quantity of water required for making concrete is found after deciding water cement ratio. For example, if water cement ratio is 0.5, for one bag of cement (50 kg), water required is  $0.5 \times 50 = 25$  kg, which is equal to 25 litres. Suitable measure is used to select required quantity of water.

Volume batching is not ideal method of batching. Wet sand has higher volume for the same weight of dry sand. It is called bulking of sand. Hence it upsets the calculated volume required.

(b) **Weight Batching:** This is the recommended method of batching. A weighing platform is used in the field to pick up correct proportion of sand and coarse aggregates. Large weigh batching plants have automatic weighing equipments.

2. **Mixing:** To produce uniform and good concrete, it is necessary to mix cement, sand and coarse aggregate, first in dry condition and then in wet condition after adding water.

The following methods are practiced:

- (a) Hand Mixing
- (b) Machine Mixing.

(a) **Hand Mixing:** Required amount of coarse aggregate for a batch is weighed and is spread on an impervious platform. Then the sand required for the batch is spread over coarse aggregate. They are mixed in dry condition by overturning the mix with shovels. Then the cement required for the batch is spread over the dry mix and mixed by shovels. After uniform texture is observed water is added gradually and mixing is continued. Full amount of water is added and mixing is completed when uniform colour and consistency is observed. The process of mixing is completed in 6–8 minutes of adding water. This method of mixing is not very good but for small works it is commonly adopted.

(b) **Machine Mixing:** In large and important works machine mixing is preferred. Figure 3.2 shows a typical concrete mixer. Required quantities of sand and coarse aggregates are placed in the drum of the mixer. 4 to 5 rotations are made for dry mixing and then required quantity of cement is added and dry mixing is made with another 4 to 5 rotations. Water is gradually added and drum is rotated for 2 to 3 minutes during which period it makes about 50 rotations. At this stage uniform and homogeneous mix is obtained.



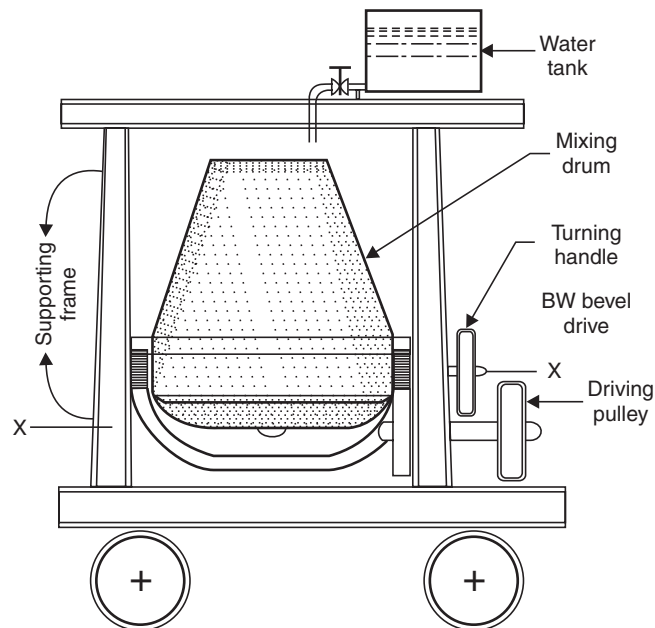


Fig. 3.2. Concrete mixer

3. **Transporting and Placing of Concrete.** After mixing concrete should be transported to the final position. In small works it is transported in iron pans from hand to hand of a set of workers. Wheel barrow and hand carts also may be employed. In large scale concreting chutes and belt conveyors or pipes with pumps are employed. In transporting care should be taken to see that segregation of aggregate from matrix of cement do not take place.

Concrete is placed on form works. The form works should be cleaned and properly oiled. If concrete is to be placed for foundation, the soil bed should be compacted well and is made free from loose soil.

Concrete should be dropped on its final position as closely as possible. If it is dropped from a height, the coarse aggregates fall early and then mortar matrix. This segregation results into weaker concrete.

4. **Compaction of Concrete:** In the process of placing concrete, air is entrapped. The entrapped air reduces the strength of concrete up to 30%. Hence it is necessary to remove this entrapped air. This is achieved by compacting the concrete after placing it in its final position. Compaction can be carried out either by hand or with the help of vibrators.

(a) **Hand Compaction:** In this method concrete is compacted by ramming, tamping, spading or by slicing with tools. In intricate portions a pointed steel rod of 16 mm diameter and about a metre long is used for poking the concrete.

(b) **Compaction by Vibrators:** Concrete can be compacted by using high frequency vibrators. Vibration reduces the friction between the particles and set the motion of particles. As a result entrapped air is removed and the concrete is compacted. The use of vibrators reduces the compaction time. When

vibrators are used for compaction, water cement ratio can be less, which also help in improving the strength of concrete. Vibration should be stopped as soon as cement paste is seen on the surface of concrete. Over vibration is not good for the concrete.

The following types of vibrators are commonly used in concreting:

- (a) Needle or immersion vibrators
- (b) Surface vibrators
- (c) Form or shutter vibrators
- (d) Vibrating tables.

Needle vibrators are used in concreting beams and columns. Surface vibrators and form vibrators are useful in concreting slabs. Vibrating tables are useful in preparing precast concrete elements.

### Curing of Concrete

Curing may be defined as the process of maintaining satisfactory moisture and temperature conditions for freshly placed concrete for some specified time for proper hardening of concrete. Curing in the early ages of concrete is more important. Curing for 14 days is very important. Better to continue it for 7 to 14 days more. If curing is not done properly, the strength of concrete reduces. Cracks develop due shrinkage. The durability of concrete structure reduces.

The following curing methods are employed:

- (a) Spraying of water
- (b) Covering the surface with wet gunny bags, straw etc.
- (c) Ponding
- (d) Steam curing and
- (e) Application of curing compounds.

(a) **Spraying of water:** Walls, columns, plastered surfaces are cured by sprinkling water.

(b) **Wet covering the surface:** Columns and other vertical surfaces may be cured by covering the surfaces with wet gunny bags or straw.

(c) **Ponding:** The horizontal surfaces like slab and floors are cured by stagnating the water to a height of 25 to 50 mm by providing temporary small hunds with mortar.

(d) **Steam curing:** In the manufacture of pre-fabricated concrete units steam is passed over the units kept in closed chambers. It accelerates curing process, resulting into the reduction of curing period.

(e) **Application of curing compounds:** Compounds like calcium chloride may be applied on the curing surface. The compound shows affinity to the moisture and retains it on the surface. It keeps the concrete surface wet for a long time.

### Properties of Concrete

Concrete has completely different properties when it is the plastic stage and when hardened. Concrete in the plastic stage is also known as *green concrete*. The properties of green concrete include:

1. Workability
2. Segregation
3. Bleeding
4. Harshness.

The properties of hardened concrete are:

1. Strength
2. Resistance to wear
3. Dimensional changes
4. Durability
5. Impermeability.

### Properties of Green Concrete

**1. Workability:** This is defined as the ease with which concrete can be compacted fully without segregating and bleeding. It can also be defined as the amount of internal work required to fully compact the concrete to optimum density. The workability depends upon the quantity of water, grading, shape and the percentage of the aggregates present in the concrete.

Workability is measured by

(a) The slump observed when the frustum of the standard cone filled with concrete is lifted and removed.

(b) The compaction factor determined after allowing the concrete to fall through the compaction testing machine.

(c) The time taken in seconds for the shape of the concrete to change from cone to cylinder when tested in Vee-Bee consistometer.

The suggested values of workability for different works are as shown in Table 3.2.

**Table 3.2.** Suggested values of workability

<i>Application</i>	<i>Slump</i>	<i>Compaction Factor</i>	<i>Time in Vee-Bee</i>
1. Concreting of shallow sections with vibrations	—	0.75 – 0.80	10 – 20
2. Concreting of light reinforced sections with vibrators	—	0.80 – 0.85	5 – 10
3. Concreting of lightly reinforced sections without vibrations and heavily reinforced sections with vibrations	25 – 75 mm	0.85 – 0.92	2 – 5
4. Concreting of heavily reinforced sections without vibration	75 – 125 mm	More than 0.92	—

**2. Segregation:** Separation of coarse particles from the green concrete is called segregation. This may happen due to lack of sufficient quantity of finer particles in concrete or due to throwing of the

concrete from greater heights at the time of placing the concrete. Because of the segregation, the cohesiveness of the concrete is lost and honey combing results. Ultimately it results in the loss of strength of hardened concrete. Hence utmost care is to be taken to avoid segregation.

**3. Bleeding:** This refers to the appearance of the water along with cement particles on the surface of the freshly laid concrete. This happens when there is excessive quantity of water in the mix or due to excessive compaction. Bleeding causes the formation of pores and renders the concrete weak. Bleeding can be avoided by suitably controlling the quantity of water in the concrete and by using finer grading of aggregates.

**4. Harshness:** Harshness is the resistance offered by concrete to its surface finish. Harshness is due to presence of lesser quantity of fine aggregates, lesser cement mortar and due to use of poorly graded aggregates. It may result due to insufficient quantity of water also. With harsh concrete it is difficult to get a smooth surface finish and concrete becomes porous.

**Properties of Hardened Concrete**

**1. Strength:** The characteristic strength of concrete is defined as the compressive strength of 150 mm size cubes after 28 days of curing below which not more than 5 per cent of the test results are expected to fail. The unit of stress used is N/mm<sup>2</sup>. IS 456 grades the concrete based on its characteristic strength as shown in Table 3.3.

**Table 3.3.** Grades of concrete

Grade	M <sub>10</sub>	M <sub>15</sub>	M <sub>20</sub>	M <sub>25</sub>	M <sub>30</sub>	M <sub>35</sub>	M <sub>40</sub>
Characteristic strength in M N/mm <sup>2</sup>	10	15	20	25	30	35	40

Till year 2000, M<sub>15</sub> concrete was permitted to be used for reinforced concrete works. But IS 456–2000 specifies minimum grade of M<sub>20</sub> to be used for reinforced concrete works.

Strength of concrete depends upon the amount of cement content, quality and grading of aggregates, water cement ratio, compaction and curing. Strength of concrete is gained in the initial stages. In 7 days the strength gained is as much as 60 to 65 per cent of 28 days strength. It is customary to assume the 28 days strength as the full strength of concrete. However concrete gains strength after 28 days also. The characteristic strength may be increased by the as factor given in Table 3.4.

**Table 3.4.** Effect of age factor on strength of concrete

Minimum age of member when design load is expected.	1 month	3 months	6 months	12 months
Age factor	1.0	1.10	1.15	1.20

The tensile strength may be estimated from the formula  $f_t = 0.7\sqrt{f_{ck}}$  N/mm<sup>2</sup>, where  $f_{ck}$  is the characteristic compressive stress. The modulus of elasticity may be estimated from the formula:

$$E = 50\sqrt{f_{ck}} \text{ N/mm}^2.$$

**2. Dimensional Change:** Concrete shrinks with age. The total **shrinkage** depends upon the constituents of concrete, size of the member and the environmental conditions. Total shrinkage is approximately 0.0003 of original dimension.

The permanent dimension change due to loading over a long period is termed as **creep**. Its value depends upon the stress in concrete, the age of the concrete at the time of loading and the duration of the loading. The ultimate creep strain may be estimated from the values of creep coefficient. The creep coefficient is defined as ultimate creep strain divided by the elastic strain at the age of loading. These values are listed in Table 3.5.

**Table 3.5.** Creep coefficient based on the age of loading

Age of Loading	7 days	28 days	1 year
Creep Coefficient	2.2	1.6	1.1

The size of concrete may change due to thermal expansion also. The coefficient of thermal expansion depends upon the nature of cement, the type of aggregates, cement content, relative humidity and the size of the sections of the structural elements. Table 3.6 shows the coefficient of thermal expansion of concrete with different types of aggregates.

**Table 3.6.** Coefficient of thermal expansion

Type of Aggregate	Coefficient of Thermal Expansion/ $C^{\circ}$
1. Quartzite	$(1.2 \text{ to } 1.3) \times 10^{-5}$
2. Sand stone	$(0.9 \text{ to } 1.2) \times 10^{-5}$
3. Granite	$(0.7 \text{ to } 0.95) \times 10^{-5}$
4. Basalt	$(0.8 \text{ to } 0.95) \times 10^{-5}$

**3. Durability:** Environmental forces such as weathering, chemical attack, heat, freezing and thawing try to destroy concrete. The period of existence of concrete without getting adversely affected by these forces is known as durability. Generally dense and strong concretes have better durability. The cube crushing strength alone is not a reliable guide to the durability. Concrete should have an adequate cement content and should have low water cement ratio.

**4. Impermeability:** This is the resistance of concrete to the flow of water through its pores. Excess water during concreting leaves a large number of continuous pores leading to the permeability. Since the permeability reduces the durability of concrete, it should be kept very low by using low water cement ratio, dense and well graded aggregates, good compaction and continuous curing at low temperature conditions. The cement content used should be sufficient to provide adequate workability with low water cement ratio and the available compaction method.

## Tests on Concrete

The following are some of the important tests conducted on concrete:

1. Slump test.
2. Compaction factor test.
3. Crushing strength test.

**1. Slump Test:** This test is conducted to determine the workability of concrete. It needs a slump cone for test (Fig. 3.3). Slump cone is a vessel in the shape of a frustum of a cone with diameter at bottom 200 mm and 50 mm at top and 300 mm high. This cone is kept over a impervious platform and is filled with concrete in four layers. Each layer is tamped with a 16 mm pointed rod for 25 times. After filling completely the cone is gently pulled up. The decrease in the height of the concrete is called slump. Higher the slump, more workable is the concrete. The desired values of slumps for various works have been shown in Table 3.2.

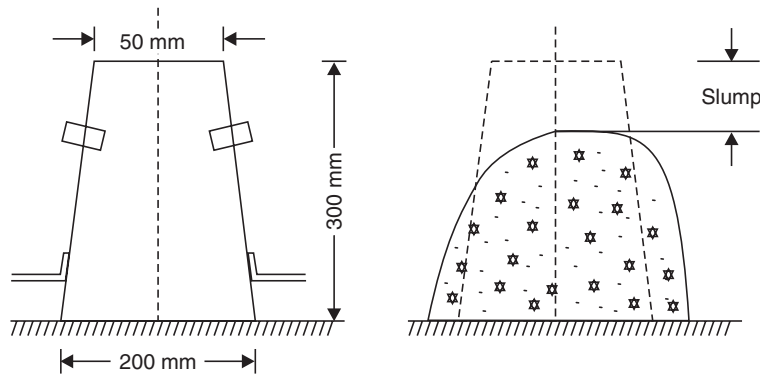


Fig. 3.3. Slump test

**2. Compaction Factor Test:** This is another test to identify the workability of concrete. This test is conducted in the laboratory. The test equipment consists of two hoppers and a cylinder fixed to a stand, the dimensions and the distances between the three vessels being standardized. Vessel A and B are having hinged bottoms whereas cylinder C is having fixed bottom. [Ref. Fig. 3.4]

Top vessel A is filled with the concrete to be tested. As soon as it is filled, the hinged door is opened. Concrete is collected in vessel B. Then the hinged door of B is opened to collect concrete in cylinder C. The concrete in cylinder C is weighted. Let it be  $W_1$ .

Now cylinder is again filled with the sample of concrete in 50 mm layers, which is compacted by ramming and vibrating. Then the weight of compacted concrete is determined. Let this weight be  $W_2$ .

The ratio  $W_1/W_2$  is termed as compaction factor. The specified values of compaction factor for different works are already listed in Table 3.2.

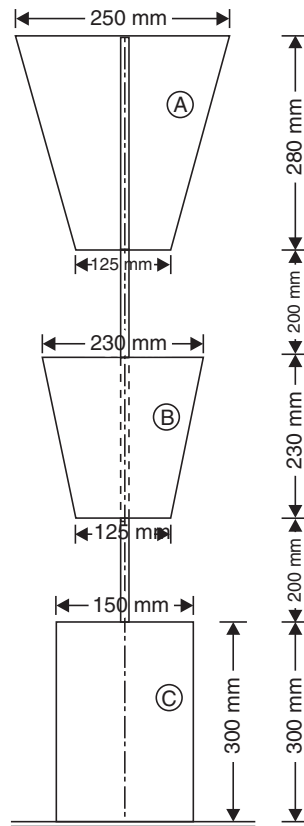


Fig. 3.4. Compaction factor test

**3. Crushing Strength Test:** Metallic moulds of size  $150\text{ mm} \times 150\text{ mm} \times 150\text{ mm}$  are used for casting concrete cubes. Before filling mould, it is properly oiled on its inner surfaces, so that cubes can be easily separated. Fresh cube is filled with concrete to be tested in 3 layers and kept in the room. After 24 hours, cube is removed from the mould and kept under water for curing. After 28 days of curing cubes are tested in the compression testing machine. In this test cubes are placed over the smooth surface which is in contact with side plates of mould. The crushing load is noted and crushing strength is found as load divided by surface area ( $150 \times 150\text{ mm}^2$ ).

Code specify the desirable strength of concrete for 3 days and 7 days for quick assessment of strength of concrete.

### Desirable Properties of Concrete

Appropriate quality and quantity of cement, fine aggregate, coarse aggregate and water should be used so that the green concrete has the following properties:

- (a) Desired workability
- (b) No segregation in transporting and placing
- (c) No bleeding and
- (d) No harshness.

Hardened concrete should have

- (a) required characteristic strength
- (b) minimum dimensional changes
- (c) good durability
- (d) impermeable
- (e) good resistance to wear and tear.

### Uses of Concrete

1. As bed concrete below column footings, wall footings, on wall at supports to beams
2. As sill concrete
3. Over the parapet walls as coping concrete
4. For flagging the area around buildings
5. For pavements
6. For making building blocks.

However major use of concrete is as a major ingredient of reinforced and prestressed concrete. Many structural elements like footings, columns, beams, chejjas, lintels, roofs are made with R.C.C. Cement concrete is used for making storage structures like water tanks, bins, silos, bunkers etc. Bridges, dams, retaining walls are R.C.C. structures in which concrete is the major ingredient.

## 3.2 REINFORCED CEMENT CONCRETE (R.C.C.)

Concrete is good in resisting compression but is very weak in resisting tension. Hence reinforcement is provided in the concrete wherever tensile stress is expected. The best reinforcement is steel, since tensile strength of steel is quite high and the bond between steel and concrete is good. As the elastic modulus of steel is high, for the same extension the force resisted by steel is high compared to concrete. However in tensile zone, hair cracks in concrete are unavoidable. Reinforcements are usually in the form of mild steel or ribbed steel bars of 6 mm to 32 mm diameter. A cage of reinforcements is prepared as per the design requirements, kept in a form work and then green concrete is poured. After the concrete hardens, the form work is removed. The composite material of steel and concrete now called R.C.C. acts as a structural member and can resist tensile as well as compressive stresses very well.

### Properties of R.C.C./Requirement of Good R.C.C.

1. It should be capable of resisting expected tensile, compressive, bending and shear forces.
2. It should not show excessive deflection and spoil serviceability requirement.
3. There should be proper cover to the reinforcement, so that the corrosion is prevented.
4. The hair cracks developed should be within the permissible limit.
5. It is a good fire resistant material.
6. When it is fresh, it can be moulded to any desired shape and size.



7. Durability is very good.
8. R.C.C. structure can be designed to take any load.

### Uses of R.C.C.

It is a widely used building material. Some of its important uses are listed below:

1. R.C.C. is used as a structural element, the common structural elements in a building where R.C.C. is used are:
  - (a) Footings
  - (b) Columns
  - (c) Beams and lintels
  - (d) Chejjas, roofs and slabs.
  - (e) Stairs.
2. R.C.C. is used for the construction of storage structures like
  - (a) Water tanks
  - (b) Dams
  - (c) Bins
  - (d) Silos and bunkers.
3. It is used for the construction of big structures like
  - (a) Bridges
  - (b) Retaining walls
  - (c) Docks and harbours
  - (d) Under water structures.
4. It is used for pre-casting
  - (a) Railway sleepers
  - (b) Electric poles
5. R.C.C. is used for constructing tall structures like
  - (a) Multistorey buildings
  - (b) Chimneys
  - (c) Towers.
6. It is used for paving
  - (a) Roads
  - (b) Airports.
7. R.C.C. is used in building atomic plants to prevent danger of radiation. For this purpose R.C.C. walls built are 1.5 m to 2.0 m thick.

### 3.3 REINFORCED BRICK CONCRETE (RBC)

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It is the combination of reinforcement, brick and concrete. It is well known fact that concrete is very weak in tension. Hence in the slabs, lintels and beams the concrete in the portion below the neutral axis do not participate in resisting the load. It acts as a filler material only. Hence to achieve economy the concrete in tensile zone may be replaced by bricks or tiles. Dense cement mortar is used to embed the reinforcement. The reinforcement may be steel bars, expanded mesh etc.

### 3.4 PRESTRESSED CONCRETE (PSC)

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Strength of concrete in tension is very low and hence it is ignored in R.C.C. design. Concrete in tension is acting as a cover to steel and helping to keep steel at desired distance. Thus in R.C.C. lot of concrete

is not properly utilized. Prestressing the concrete is one of the method of utilizing entire concrete. The principle of prestressed concrete is to introduce calculated compressive stresses in the zones wherever tensile stresses are expected in the concrete structural elements. When such structural element is used stresses developed due to loading has to first nullify these compressive stresses before introducing tensile stress in concrete. Thus in prestressed concrete entire concrete is utilized to resist the load. Another important advantage of PSC is hair cracks are avoided in the concrete and hence durability is high. The fatigue strength of PSC is also more. The deflections of PSC beam is much less and hence can be used for longer spans also.

PSC is commonly used in the construction of bridges, large column free slabs and roofs. PSC sleepers and electric piles are commonly used.

The material used in PSC is high tensile steel and high strength steel. The tensioning of wires may be by pretensioning or by post tensioning. Pretensioning consists in stretching the wires before concreting and then releasing the wires. In case of post tensioning, the ducts are made in concrete elements. After concrete of hardens, prestressing wires are passed through ducts. After stretching wires, they are anchored to concrete elements by special anchors.

### 3.5 FIBRE-REINFORCED CONCRETE (FRC)

Plain concrete possesses deficiencies like low tensile strength, limited ductility and low resistance to cracking. The cracks develop even before loading. After loading micro cracks widen and propagate, exposing concrete to atmospheric actions. If closely spaced and uniformly dispersed fibres are provided while mixing concrete, cracks are arrested and static and dynamic properties are improved. Fibre reinforced concrete can be defined as a composite material of concrete or mortar with discontinuous and uniformly distributed fibres. Commonly used fibres are of steel, nylon, asbestos, coir, glass, carbon and polypropylene. The length to lateral dimension of fibres range from 30 to 150. The diameter of fibres vary from 0.25 to 0.75 mm.

Fibre reinforced concrete is having *better tensile strength, ductility and resistance to cracking*.

#### Uses of FRC

1. For wearing coat of air fields, roads and refractory linings.
2. For manufacturing precast products like pipes, stairs, wall panels, manhole covers and boats.
3. Glass fibre reinforced concrete is used for manufacturing doors and window frames, park benches, bus shelters etc.
4. Carbon FRC is suitable for structures like cladding and shells.
5. Asbestos FRC sheets are commonly used as roofing materials.

### 3.6 CELLULAR CONCRETE

It is a light weight concrete produced by introducing large voids in the concrete or mortar. Its density varies from  $3 \text{ kN/m}^3$  to  $8 \text{ kN/m}^3$  whereas plain concrete density is  $24 \text{ kN/m}^3$ . It is also known as aerated, foamed or gas concrete.

**Properties of cellular concrete:** It has the following properties:

1. It has low weight.
2. It has good fire resistance.
3. It has good thermal insulation property.
4. Thermal expansion is negligible.
5. Freezing and thawing problems are absent.
6. Sound absorption is good.
7. It has less tendency to spall.

#### Uses of Cellular Concrete

1. It is used for the construction of partition walls.
2. It is used for partitions for heat insulation purposes.
3. It is used for the construction of hollow filled floors.

### 3.7 FERRO-CEMENT

The term ferro-cement implies the combination of ferrous product with cement. Generally this combination is in the form of steel wires meshes embedded in a portland cement mortar. Wire mesh is usually of 0.8 to 1.00 m diameter steel wires at 5 mm to 50 mm spacing and the cement mortar is of cement sand ratio of 1:2 or 1:3. 6 mm diameter bars are also used at large spacing, preferably in the corners. Sand may be replaced by baby jelly. The water cement ratio used is between 0.4 to 0.45.

Ferro-cement reinforcement is assembled into its final desired shape and plastered directly. There is no need for form work. Minimum two layers of reinforcing steel meshes are required. According to American Concrete Institute "Ferro cement is a thin walled reinforced concrete construction where usually a hydraulic cement is reinforced with layers of continuous and relatively small diameter mesh. The mesh used may be metallic or any other suitable material."

Ferro-cement is fast emerging as an alternate material for timber. The history of ferro-cement goes back to 1843 (even before RCC). Joseph Louis Lambet constructed several rowing boats, plant plots and garden seats using ferro-cement. In early 1940's noted Italian engineer and architect Pier Luigi Nervi carried out scientific tests on ferro-cement and used it to replace wood wherever possible. He built small tonnage vessels, the largest being 165 tons motor sailor. Nervi also pioneered the architectural use of ferro-cement in buildings. Ferro-cement can be given the finish of teak wood, rose wood etc. and even for making tables, chairs and benches it can be used.

### Properties of Ferro-cement

1. Its strength per unit mass is high.
2. It has the capacity to resist shock load.
3. It can be given attractive finish like that of teak and rose wood.
4. Ferro cement elements can be constructed without using form work.
5. It is impervious.

### Uses of Ferro-cement

It can be used for making:

1. Partition walls
2. Window frames, chejjas and drops
3. Shelf of cupboards
4. Door and window shutters
5. Domestic water tanks
6. Precast roof elements
7. Reapers and rafter required for supporting roof tiles.
8. Pipes
9. Silos
10. Furnitures
11. Manhole covers
12. Boats.

## QUESTIONS

1. What is cement concrete? Explain the function of each ingredient and state common proportions of the ingredients used for different works.
2. What do you understand by batching of concrete? Briefly explain different methods of batching.
3. Explain different methods of mixing aggregates.
4. Why concrete should be compacted after placing? Explain different methods of compaction. Bring out their advantages and disadvantages.
5. What is meant by curing of concrete? Why it is necessary and how it is made?
6. Write short notes on
  - (a) Workability of concrete
  - (b) Segregation of concrete and
  - (c) Bleeding of concrete.

7. Write short note on water cement ratio.
8. What do you understand by  $M_{20}$  concrete? How this grade is determined?
9. Explain the various causes for dimensional changes in the hardened concrete.
10. Write short notes on the following tests on concrete:
  - (a) Slump test
  - (b) Compaction factor test
  - (c) Crushing strength test.
11. What are the desired properties of concrete?
12. List the various works where concrete is used.
13. What is R.C.C.? Briefly write on desirable properties and uses of concrete.
14. Write short notes on
  - (a) Reinforced brick concrete
  - (b) Prestressed concrete
  - (c) Fibre reinforced concrete
  - (d) Cellular concrete and
  - (e) Ferro-cement.

## Metals as Building Materials

Various metals used for building works be broadly classified as ferrous metals and non-ferrous metals. The properties and uses of ferrous metals and some of important non-ferrous materials like aluminium and copper are explained in this chapter.

### 4.1 FERROUS METALS

A ferrous material is the one in which iron is a main constituent. Iron ore is first converted into pig iron and then pig iron is subjected to various metallurgical processes to mix different percentage of carbon and to get the following three useful ferrous materials:

1. Cast iron—carbon content 1.7% to 4.5%
2. Wrought iron—carbon content 0.05% to 0.15%
3. Steel—carbon content 0.25% to 0.25%.

All ferrous materials contain about 0.5 to 3% silica, less than 2% manganese, 0.15% sulphur and 0.6% phosphorous.

**1. Cast Iron:** Important *properties* of cast iron are:

- (a) Compression strength is  $700 \text{ N/mm}^2$  and tensile strength is  $150 \text{ N/mm}^2$ .
- (b) It is brittle and does not absorb shocks
- (c) Its specific gravity is 7.5.
- (d) Its structure is coarse, crystalline and fibrous.
- (e) It cannot be magnetised.
- (f) It does not rust-easily.
- (g) It has low melting point of about  $1200^\circ\text{C}$ .

**Uses of Cast Iron:**

- (a) 1. It is used for making rain water and sanitary pipes, sanitary fittings and manhole covers.
2. It is used for making railings and spiral stair cases.
3. Fire gratings, cover for pumps and motors and brackets are made with cast irons.

**2. Wrought Iron:** It is almost pure iron. It contains less than 0.15% carbon. Attempts are made to reduce the other impurities during the process of manufacturing.

**Properties of Wrought Iron:**

1. Its ultimate compressive strength is  $200 \text{ N/mm}^2$  and ultimate tensile strength is  $375 \text{ N/mm}^2$ .
2. It is ductile and brittle.
3. Its unit weight is  $77 \text{ kN/m}^3$ .
4. It melts at about  $1500^\circ\text{C}$ . It becomes so soft at  $900^\circ\text{C}$  that two pieces can be joined by hammering.
5. It can absorb shocks very well.
6. It forms temporary magnets but it cannot be magnetised permanently.
7. It rusts more easily.

**Uses of Wrought Iron:**

1. It is used for making nails nuts and bolts, wires and chains.
2. It is used for making roofing sheets, grills, fences, window guards etc.

**3. Steel:** It is extensively used building material. The following three varieties of steel are extensively used:

- (a) Mild steel
- (b) High carbon steel and
- (c) High tensile steel.

(a) **Mild Steel:** It contains a maximum of 0.25% carbon, 0.055% of sulphur and 0.55% of phosphorus.

**Properties of Mild Steel:**

- (i) It is malleable and ductile
- (ii) It is more elastic
- (iii) It can be magnetized permanently.
- (iv) Its specific gravity is 7.8.
- (v) Its Young's modulus is  $2.1 \times 10^5 \text{ N/mm}^2$ .
- (vi) It can be welded easily.
- (vii) It is equally strong in tension and in compression.

**Uses of Mild Steel:**

- (i) Round bars are extensively used as reinforcement in R.C.C. works.
- (ii) Rolled sections like I, T, L, C, plates etc. are used to build steel columns, beams, trusses etc.
- (iii) Tubular sections are used as poles and members of trusses.
- (iv) Plain and corrugated mild steel are used as roofing materials.
- (v) Mild steel sections are used in making parts of many machineries.

(b) **High Carbon Steel:** The carbon contents in this steel is 0.7% to 1.5%.

**Properties of Carbon Steel:**

- (i) It is more tough and elastic compared to mild steel.
- (ii) Welding is difficult.
- (iii) It can be magnetized permanently.
- (iv) It is stronger in compression than in tension.
- (v) It withstands shocks and vibrations better.

**Uses of High Carbon Steel:**

- (i) It is used for making tools such as drills, files, chisels.
- (ii) Many machine parts are made with high carbon steel since it is capable of withstanding shocks and vibrations.
- (c) **High Tensile Steel:** It contains 0.8% carbon and 0.6% manganese. The strength of this steel is quite high. High tensile steel wires are used in prestressed concrete works.

## 4.2 ALUMINIUM

It is present on the surface of earth crust in most of the rocks and clay. But to produce the metal bauxite ( $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ) is ideally suited ore.

**Properties of Aluminium**

1. It is having silver colour and bright lustre.
2. It is very light in weight.
3. It is good conductor of electricity.
4. It has very good resistance to corrosion.
5. It melts at  $66^\circ\text{C}$ .
6. It is highly ductile and malleable.
7. It has high strength to weight ratio.

**Uses of Aluminium**

1. It is used to make door and window frames.
2. Aluminium structural members are becoming popular.
3. Aluminium wires are used as conductors of electricity.
4. It is used as a foil.
5. Aluminium powder serves as pigments in paints.





## Miscellaneous Building Materials

Glass, plastics, bitumen, asbestos, paints, distemper and varnishes are some of the miscellaneous materials used in building constructions. Their properties and uses are briefly presented in this chapter.

### 5.1 GLASS

Silica is the main constituent of glass. But it is to be added with sodium potassium carbonate to bring down melting point. To make it durable lime or lead oxide is also added. Manganese oxide is added to nullify the adverse effects of unwanted iron present in the impure silica. The raw materials are ground and sieved. They are mixed in specific proportion and melted in furnace. Then glass items are manufactured by blowing, flat drawing, rolling and pressing.

#### Important Properties of Glass

1. It absorbs, refracts or transmits light. It can be made transparent or translucent.
2. It can take excellent polish.
3. It is an excellent electrical insulator.
4. It is strong and brittle.
5. It can be blown, drawn or pressed.
6. It is not affected by atmosphere.
7. It has excellent resistance to chemicals.
8. It is available in various beautiful colours.
9. With the advancement in technology, it is possible to make glass lighter than cork or stronger than steel.
10. Glass panes can be cleaned easily.

#### Types of Glass

The glass may be broadly classified as:

1. Soda-lime glass
2. Potash lime glass

3. Potash lead glass
4. Common glass and
5. Special glasses.
  1. *Soda Lime Glass*: It is mainly a mixture of sodium silicate and calcium silicate. It is fusible at low temperature. In the fusion condition it can be blown or welded easily. It is colourless. It is used as window panes and for the laboratory tubes and apparatus.
  2. *Potash Lime Glass*: It is mainly a mixture of potassium silicate and calcium silicate. It is also known as hard glass. It fuses at high temperature. It is used in the manufacture of glass articles which have to with stand high temperatures.
  3. *Potash Lead Glass*: It is mainly a mixture of potassium silicate and lead silicate. It possesses bright lustre and great refractive power. It is used in the manufacture of artificial gems, electric bulbs, lenses, prisms etc.
  4. *Common Glass*: It is mainly a mixture of sodium silicate, calcium silicate and iron silicate. It is brown, green or yellow in colour. It is mainly used in the manufacture of medicine bottles.
  5. *Special Glasses*: Properties of glasses can be suitably altered by changing basic ingredients and adding few more ingredients. It has now emerged as versatile material to meet many special requirement in engineering. The following is the list of some of the special glasses:
 

(a) Fibre glass	(b) Foam glass
(c) Bullet proof glass	(d) Structural glass
(e) Glass black	(f) Wired glass
(g) Ultraviolet ray glass	(h) Perforated glass.

## 5.2 PLASTICS

Plastic is an organic material prepared out of resin. It may or may not contain fillers, plasticisers and solvents. Plastic may be defined as a natural or synthetic organic material which are having the property of being plastic at some stage of their manufacture when they can be moulded to required size and shape.

Shellac and bitumen are the natural resins used as plastic for a long time. In 1907, Blackland produced synthetic resin from the reaction of phenol and formaldehyde. The resin was hardened under pressure and heat to produce useful plastic articles.

### Types of Plastics

Primarily there are two types of plastics:

1. Thermosetting and
2. Thermoplastic.

1. *Thermosetting Plastics*: It needs momentary heated condition and great pressure during shaping. When heated cross linkage is established between the molecules and chemical reaction takes place. During this stage shape can be changed with pressure. This change is not reversible. The scrap of such plastic is not reusable. Bakelite is an example of such plastic.

2. *Thermoplastic*: In this variety, the linkage between the molecules is very loose. They can be softened by heating repeatedly. This property helps for reuse of waste plastic. These plastic need time to cool down and harden. These plastics are to be kept in moulds till cooling takes place completely. Bitumen, cellulose and shellac are the examples of this variety of plastics.

### Properties of Plastics

1. *Colour*: Some plastics are completely transparent. Using pigments plastics of any attractive colour can be produced.
2. *Dimensional Stability*: It is dimensionally stable to a great extent.
3. *Durability*: Plastic offers great resistance to moisture and chemicals and hence more durable.
4. *Electrical Insulation*: The plastics possess excellent electrical insulating property.
5. *Fire Resistance*: The phenol-formaldehyde and urea-formaldehyde plastics resist fire to a great extent and hence they are used as fire proofing materials.
6. *Strength*: The plastics are reasonably strong. Their strength may be increased by reinforcing with various fibrous materials. Attempts are being made to produce structurally sound plastics.
7. *Specific Gravity*: The specific gravity of plastics is very low and hence convenient to handle.
8. *Ductility*: The plastics are not ductile and hence they fail without giving warning.
9. *Fixing*: Plastics can be bolted, drilled, glued, clamped or simply push fitted in position.
10. *Maintenance*: There is no maintenance cost for plastic articles *i.e.*, they do not need painting and polishing.

### Uses of Plastics

There are variety of plastics made to suit different uses. The typical uses of plastics in buildings is listed below:

1. Corrugated and plain sheets for roofing.
2. For making jointless flooring.
3. Flooring tiles.
4. Overhead water tanks.
5. Bath and sink units.
6. Cistern hall floats.
7. Decorative laminates and mouldings.
8. Window and door frames and shutters for bathroom doors.
9. Lighting fixtures.
10. Electrical conduits.
11. Electrical insulators.
12. Pipes to carry cold waters.

### 5.3 BITUMEN

Asphalt, bitumen and tar are referred as bituminous materials, which are essentially hydrocarbon materials. The **asphalt** is a mixture of inert mineral matter lime alumina, lime, silica etc. and a hydrocarbon known as asphaltic bitumen. In some places like Trinidad and Bermudez, asphalt is available in nature at a depth of 3 to 60 metres. It is known as **natural asphalt**. Common variety used all over the world is **residual asphalt**, which is obtained by fractional distillation of crude petroleum oil. Bitumen is the binding material which is present in asphalt. It is a hydrocarbon. It is obtained by partial distillation of crude oil. It contains 87 per cent carbon, 11 per cent hydrogen and 2 per cent oxygen.

**Tar** is obtained in the destructive distillation of coal, wood or other organic materials. When coal or wood is heated to redness in a closed chamber, it yields volatile product and residue coke. After separating and cooling volatile product gives tar.

Comparison between asphalt, bitumen and tar is presented in Table 5.1.

**Table 5.1.** Comparison between asphalt, bitumen and tar

<i>S. No.</i>	<i>Property</i>	<i>Asphalt</i>	<i>Bitumen</i>	<i>Tar</i>
1.	Colour	Blackish brown	Dark with slight reddish tinge	Deep dark
2.	Carbon content	Low	Moderate	High
3.	State	Solid or semisolid	Solid	Viscous liquid
4.	Effect on heating	Burns with a smoke flame and becomes plastic	Melts	Becomes more fluid.
5.	Setting time	Less	Less	More
6.	Adhesive power	Less	More	Most
7.	Resistance to acid	More	More	Less
8.	Use	As damp proof course, for paints, as roofing felt and for road works.	As damp proof course and as roofing felt.	For preserving timber.

### 5.4 ASBESTOS

Asbestos is a general name for several varieties of fibrous minerals which are available in nature. But presently, most of the commercial asbestos produced is 'chriotile'  $[Mg_6SiO_{11}(OH)_6 \cdot H_2O]$ .

#### Properties of Asbestos

1. It is flexible, soft and non-porous.
2. It is fire proof and acid proof material.
3. It is a good insulator of heat and electricity.

4. When it is mixed with cement and water, it retains shape firmly.
5. Its colour is brown or grey.
6. It can be cut into pieces or can be drilled.
7. It possesses high tensile strength in the direction of its fibres.
8. Its specific gravity is 3.10.

### Uses of Asbestos

1. Asbestos cement sheets are the cheapest roofing materials.
2. Asbestos cement pipes are used as down take pipes of rain water from the roof.
3. With bitumen it forms good damp proof layer.
4. It is used for preparing fire proof ropes and clothes.
5. It is used as covering material for fuse and electric switch boxes.
6. It is useful for insulating boilers, furnaces etc.

## 5.5 PAINTS

Paints are applied on the surfaces of timber, metals and plastered surfaces as a protective layer and at the same time to get pleasant appearance. Paints are applied in liquid form and after sometime the volatile constituent evaporates and hardened coating acts as a protective layer.

### Constituents of Paint

The essential constituents of paints are:

1. Base
2. A vehicle
3. A pigment
4. A drier and
5. A thinner.

- 1. Bases:** It is a principal constituent of paint. It also possesses the binding properties. It forms an opaque coating. Commonly used bases for paints are white lead, red lead, zinc oxide, iron oxide, titanium white, aluminium powder and lithophone. A lead paint is suitable for painting iron and steel works, as it sticks to them well. However it is affected by atmosphere action and hence should not be used as final coat. While zinc forms good base but is costly. Lithophone, which is a mixture of zinc sulphate and barytes, is cheap. It gives good appearance but is affected by day light. Hence it is used for interior works only.
- 2. Vehicles:** The vehicles are the liquid substances which hold the ingredients of a paint in liquid suspension and allow them to be applied on the surface to be painted. Linseed oil, Tung oil and Nut oil are used as vehicles in paints. Of the above four oils, linseed oil is very commonly used vehicles. Boiling makes the oil thicker and darker. Linseed oil reacts with oxygen and hardens by forming a thin film.
- 3. Pigment:** Pigments give required colour for paints. They are fine particles and have a reinforcing effect on thin film of the paint. The common pigments for different colours are: Black—Lamp black, suit and charcoal black.

Red—venedion red, red lead and Indian red.

Brown—burned timber, raw and burned sienna

Green—chrome green, copper sulphate.

Blue—prussian blue and ultra marine

Yellow—ochre and chrome yellow.

**4. The Drier:** These are the compounds of metal like lead, manganese, cobalt. The function of a drier is to absorb oxygen from the air and supply it to the vehicle for hardening. The drier should not be added until the paint is about to be used. The excess drier is harmful because it destroys elasticity and causes flaking.

**5. The Thinner:** It is known as solvent also. It makes paint thinner and hence increases the coverage. It helps in spreading paint uniformly over the surface. Turpentine and naphtha are commonly used thinners. After paint applied, thinner evaporates and paint dries.

### Properties of an Ideal Paint

1. It should be possible to apply easily and freely.
2. It should dry in reasonable time.
3. It should form hard and durable surface.
4. It should not be harmful to the health of workers.
5. It should not be easily affected by atmosphere.
6. It should possess attractive and pleasing appearance.
7. It should form a thin film of uniform nature *i.e.*, it should not crack.
8. It should possess good spreading power.
9. It should be cheap.

### Types of Paints

Depending upon their constituents there are various types of paints. A brief description of some of them which are commonly used are given below:

- 1. Oil Paint:** These paints are applied in three coats—primer, undercoat and finishing coat. The presence of dampness while applying the primer adversely affects the life of oil paint. This paint is cheap and easy to apply.
- 2. Enamel Paint:** It contains white lead, oil, petroleum spirit and resinous material. The surface provided by it resists acids, alkalies and water very well. It is desirable to apply a coat of titanium white before the coat of enamel is applied. It can be used both for external and internal walls.
- 3. Emulsion Paint:** It contains binding materials such as polyvinyl acetate, synthetic resins etc. It dries in  $1\frac{1}{2}$  to 2 hours and it is easy to apply. It is more durable and can be cleaned with water. For plastered surfaces, first a coat of cement paint should be applied and then the emulsion paint. Emulsion paint needs sound surfaces.
- 4. Cement Paint:** It is available in powder form. It consists of white cement, pigment and other additives. It is durable and exhibits excellent decorative appearance. It should be applied on

rough surfaces rather than on smooth surfaces. It is applied in two coats. First coat is applied on wet surface but free from excess water and allowed to dry for 24 hours. The second coat is then applied which gives good appearance.

- 5. Bituminous Paints:** This type of paint is manufactured by dissolving asphalt or vegetable bitumen in oil or petroleum. It is black in colour. It is used for painting iron works under water.
- 6. Synthetic Rubber Paint:** This paint is prepared from resins. It dries quickly and is little affected by weather and sunlight. It resists chemical attack well. This paint may be applied even on fresh concrete. Its cost is moderate and it can be applied easily.
- 7. Aluminium Paint:** It contains finely ground aluminium in spirit or oil varnish. It is visible in darkness also. The surfaces of iron and steel are protected well with this paint. It is widely used for painting gas tanks, water pipes and oil tanks.
- 8. Anti-corrosive Paint:** It consists essentially of oil, a strong drier, lead or zinc chrome and finely ground sand. It is cheap and resists corrosion well. It is black in colour.

### Application of Paint

Preparation of surface for application of paint is the most important part in painting. The surface to be painted should not be oily and it should be free from flakes of the old paint. Cracks in the surface should be filled with putty and then with sand paper. Then primer is applied. Painting work should be carried out in dry weather. The under coats and first coats must be allowed to dry before final coat is applied.

## 5.6 DISTEMPERS

Distempers are the cheaper variety of paints in which chalk is used as base and water is used as a carrier. The emulsifying agent which is commonly used is glue or casein. Distempers are available in powder form or in the form of paste. They are to be mixed with hot water before use.

The surface to be distempered should be thoroughly rubbed and cleaned. The cracks, if any should be filled by lime putty. The surface should be kept dry for about two months before applying distemper. Thus a primary coat is applied and is allowed to dry. Distemper is usually applied in two coats.

### Properties of Distemper

1. They are generally light in colour.
2. The coatings are generally thick.
3. They give reflective coating.
4. They are less durable than oil paints but are cheaper.

## 5.7 VARNISHES

Varnish is the solution of resins or resinous substances like amber, copal, shellac, gum resin etc. in solvents like oil, turpentine, alcohol etc. Depending upon the solvents used varnishes are classified as,



oil varnishes, turpentine varnishes, spirit varnishes and water varnishes. The desirable characteristics of an ideal varnish are

1. It should give glossy surface.
2. Should be durable.
3. It should dry rapidly after application.
4. It should not develop cracks after drying.

It is commonly used on wooden surfaces.

## 5.8 SOLID AND HOLLOW CONCRETE BLOCKS

Solid and hollow concrete blocks are manufactured in factories to meet the requirements of building blocks in cities and towns. These blocks may be called as artificial stones, since they replace the stones in the masonry construction. They are manufactured with lean mixes of cement, sand and aggregates of sizes less than 12 mm. Instead of sharp edged aggregates, round aggregates are preferred in the manufacture of these blocks. The properties and uses of these blocks is given in this article.

(i) **Solid Concrete Blocks:** Solid concrete blocks of size 400 mm × 200 mm × 150 mm are commonly manufactured. To reduce the weight of the block no fine concretes are preferred. No fine concrete is the concrete in which fine aggregate is not used, but round aggregates of size less than 12 mm are used. IS:2185 (part I) 1983 covers the requirement, for such blocks.

The blocks should satisfy the strength requirement of 4 N/mm<sup>2</sup>. Their density should be as low as possible, so that handling is not difficult. They should have sharp edges which are at right angles to each other.

These blocks are used for load bearing wall construction also.

(ii) **Hollow Concrete Blocks:** To reduce the weight of concrete blocks, they may be made hollow as shown in Fig. 5.1. Hollow blocks of sizes 400 mm × 200 mm × 190 mm (nominal size 400 × 200 × 200 mm) and also of sizes 400 mm × 300 mm × 190 mm (nominal size 400 × 300 × 200 mm) are manufactured. IS:2185 (part I) 1983 covers the specifications for these blocks.

These block need richer mixes. Fine aggregates upto 60% and coarse aggregates upto 40% are used.

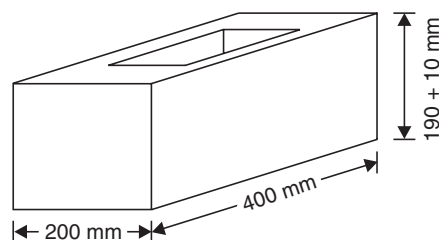


Fig. 5.1. Hollow concrete block

These blocks also should satisfy the strength requirement of 4 N/mm<sup>2</sup>. They should have truly right angled corners.

Advantage of using concrete blocks is that the construction activity is fast. Mortar requirement for finishing the surface is less. Pointing alone is sufficient, in other words plastering is not necessary. Table 5.2 gives the differences between solid and hollow concrete blocks.

**Table 5.2.** Differences between solid and hollow concrete blocks

S. No.	Solid Concrete Blocks	Hollow Concrete Blocks
1.	Solid in nature	Hollow in nature
2.	More in weight	Less in weight
3.	Conductivity of heat is high (less thermal insulation)	Conductivity of heat is low (more thermal insulation)
4.	It does not provide facility to conceal conduits etc.	It provides facility to conceal conduits etc.
5.	No fine concrete is preferred.	Fine aggregate is more (as high as 60%)
6.	Lean mixes are used	Needs richer mix.

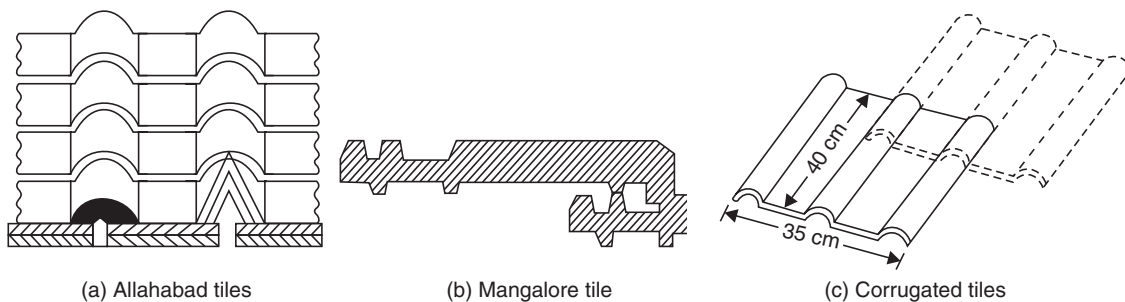
Both solid and hollow blocks can be used for the construction of load bearing as well as partition walls. They are ideally suited for the construction of compound walls.

## 5.9 ROOFING AND FLOORING TILES

These are also clay products like brick but are thin. Depending upon their use, building tiles may be further classified as

1. Roofing tiles
2. Flooring tiles and wall tiles.

1. **Roofing Tiles:** Roofing tiles are used to cover sloping roofs. They are supported on wooden reapers. Sometimes light gauge steel or steel rods are also used as reapers. After supporting on reapers these tiles should be strong enough to take load of a man safely. The tiles should be leak proof. Normally these tiles are having curved surface having ribbed sections, so that with thin section they are sufficiently



**Fig. 5.2**

strong to resist the load. However many times flat tiles are used under curved/ribbed tiles. These tiles are not subjected to load directly. They serve in reducing adverse thermal effects. Mangalore, Allahabad tiles, and corrugated tiles are popularly used roofing tiles [Ref. Fig. 5.2].

Allahabad tiles are generally laid side by side and the joints are covered with half round tiles. Mangalore tiles are red in colour and they are of interlocking type. These tiles are manufactured in Mangalore, Calicut, Cochin and Gujarat.

Corrugated tiles satisfy the requirements of appearance and leak proof but they can be easily blown away by wind.

The **desirable properties** of the roofing tiles are:

1. they should not absorb moisture more than 20 per cent by weight.
2. they should give pleasing look.
3. they should be capable of taking load of a man safely, after they are supported on reapers.
4. they should be durable.
5. they should be uniform in shape and size.
6. warpage should not exceed 2% along the edges and 1.5% along the diagonal.

**2. Flooring Tiles and Wall Tiles:** These tiles are manufactured by burning pressed green tiles twice. First they are burnt at 700°C. Then they are dipped in the glaze solution and again burnt at 1250°C to fuse them with glaze. The thickness of these tiles vary from 15 to 20 mm. These tiles are flat and they have pleasing appearance. There are two types of flooring tiles:

(a) **Glazed Tiles:** These tiles are used as finish surfaces for floors and walls in kitchen and bathrooms. These tiles are glazed and are provided with attractive colours and designs.

(b) **Mosaic Tiles:** These are precast concrete tiles with marble chips on the top surface. After fixing these tiles polishing is done.

The desirable properties of flooring and roofing tiles are:

1. Tolerance for length =  $\pm 5$  mm.
2. Tolerance for thickness =  $\pm 2$  mm.
3. Should be uniform in shape and colour.
4. They should be sound, hard and durable.
5. They should have very low percentage of water absorption.
6. They should give a clear ringing sound when struck with each other.
7. They should show good resistance to abrasion.

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## QUESTIONS

1. List the important properties of glass.
2. Write short notes on any four types of glasses.

3. Define 'Plastic'. Differentiate between thermosetting and themoplastic.
4. List the uses of plastic as building material.
5. Explain the term bitumen and state their properties and uses.
6. Differentiate between plastics and bitumen.
7. What is asbestos ? State their properties and uses.
8. Briefly explain the function of essential constituents of paints.
9. What are the requirements of an ideal paint ?
10. Bring out the differences among oil paints, enamel paints and emulsion paints.
11. Distinguish between paints and varnishes.
12. Write short note on:
  - (a) distemper
  - (b) solid and hollow concrete blocks
  - (c) flooring and roofing tiles.
13. Distinguish between solid and hollow concrete blocks.
14. Neatly sketch Allahabad and Mangalore tiles. List their desirable properties.
15. What are the requirements of good flooring tiles ?
16. Distinguish between glazed tiles and mosaaic tiles.

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## **UNIT - II**

### **BUILDING CONSTRUCTION**

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## Building Planning

Every family needs a building to reside. Apart from residential purposes buildings are required for educational, institutional, business, assembly and for industrial purposes. Buildings are required for the storage of materials also.

In this chapter basic requirements of buildings are presented and then planning of the building with respect to orientation, utility of space, energy efficiency and other requirements are explained.

### 6.1 ELEMENTS OF A BUILDING

The following are the basic elements of a building:

1. Foundation
2. Plinth
3. Walls and columns
4. Sills, lintels and chejjas
5. Doors and windows
6. Floors
7. Roofs
8. Steps, stairs and lifts
9. Finishing work
10. Building services.

The functions of these elements and the main requirement of them is presented in this article.

1. **Foundation:** Foundation is the most important part of the building. Building activity starts with digging the ground for foundation and then building it. It is the lower most part of the building. It transfers the load of the building to the ground. Its main functions and requirements are:

- (a) Distribute the load from the structure to soil evenly and safely.
- (b) To anchor the building to the ground so that under lateral loads building will not move.



(c) It prevents the building from overturning due to lateral forces.

(d) It gives level surface for the construction of super structure.

2. **Plinth:** The portion of the wall between the ground level and the ground floor level is called plinth. It is usually of stone masonry. If the foundation is on piles, a plinth beam is cast to support wall above floor level. At the top of plinth a damp proof course is provided. It is usually 75 mm thick plain concrete course.

The function of the plinth is to keep the ground floor above ground level, free of dampness. Its height is not less than 450 mm. It is required that plinth level is at least 150 mm above the road level, so that connections to underground drainage system can be made.

3. **Walls and Columns:** The function of walls and columns is to transfer the load of the structure vertically downwards to transfer it to foundation. Apart from this wall performs the following functions also:

(a) It encloses building area into different compartments and provides privacy.

(b) It provides safety from burglary and insects.

(c) It keeps the building warm in winter and cool in summer.

4. **Sills, Lintels and Chejjas:** A window frame should not be directly placed over masonry. It is placed over 50 mm to 75 mm thick plain concrete course provided over the masonry. This course is called as sill. Lintels are the R.C.C. or stone beams provided over the door and window openings to transfer the load transversely so as to see that door or window frame is not stressed unduly. The width of lintels is equal to the width of wall while thickness to be provided depends upon the opening size. Chejja is the projection given outside the wall to protect doors and windows from the rain. They are usually made with R.C.C. In low cost houses stone slabs are provided as chejjas. The projection of chejja varies from 600 mm to 800 mm. Sometimes drops are also provided to chejjas to improve aesthetic look and also to get additional protection from sun and rain.

5. **Doors and Windows:** The function of a door is to give access to different rooms in the building and to deny the access whenever necessary. Number of doors should be minimum possible. The size of the door should be of such dimension as will facilitate the movement of the largest object likely to use the door.

Windows are provided to get light and ventilation in the building. They are located at a height of 0.75 m to 0.9 m from the floor level. In hot and humid regions, the window area should be 15 to 20 per cent of the floor area. Another thumb rule used to determine the size and the number of windows is for every 30 m<sup>3</sup> of inside volume there should be 1 m<sup>2</sup> window opening.

6. **Floors:** Floors are the important component of a building. They give working/useful area for the occupants. The ground floor is prepared by filling brick bats, waste stones, gravel and well compacted with not less than 100 mm sand layer on its top. A lean concrete of 1 : 4 : 8, 100 mm thick is laid. On this a damp proof course may be provided. Then floor finishing is done as per the requirement of the owner. Cheapest floor finish for a moderate house is with 20 to 25 mm rich mortar course finished with red oxide. The costliest floor finish is mosaic or marble finishing.

Other floors are usually of R.C.C. finished as per the requirements of the owner.

7. **Roof:** Roof is the top most portion of the building which provide top cover to the building. It should be leak proof.

Sloping roof like tiled and A.C. sheet give leak proof cover easily. But they do not give provision for the construction of additional floor. Tiled roof give good thermal protection.

Flat roofs give provision for additional floors. Terrace adds to the comfort of occupants. Water tanks can be easily placed over the flat roofs.

8. **Step, Stairs and Lifts:** Steps give convenient access from ground level to ground floor level. They are required at doors in the outer wall. 250 to 300 mm wide and 150 mm rise is ideal size for steps. In no case the size of two consecutive steps be different. Number of steps required depends upon the difference in the levels of the ground and the floor. Stairs give access from floor to floor. They should consists of steps of uniform sizes.

In all public buildings lifts are to be provided for the conveniences of old and disabled persons. In hostels G + 3 floors can be built without lifts, but in residential flats maximum floors permitted without lifts is only G + 2. Lift is to be located near the entrance. Size of the lift is decided by the number of users in peak hours. Lifts are available with capacity 4 to 20 persons.

9. **Finishing:** Bottom portion of slab (ceiling), walls and top of floor need smooth finishing with plaster. Then they are provided with white wash, distemper or paints or tiles. The function of finishing work is:

- (a) Give protective cover
- (b) Improve aesthetic view
- (c) Rectify defective workmanship
- (d) Finishing work for plinth consists in pointing while for floor it consists in polishing.

10. **Building Services:** Water supply, sanitation and drainage works, electric supply work and construction of cupboards and show cases constitute major building services.

For storing water from municipal supply or from tanker a sump is built in the house property near street. From the sump water is pumped to over head tanks placed on or above roof level so as to get water all the 24 hours. Plumbing work is made so as to get water in kitchen, bathrooms, water closets, sinks and garden taps.

For draining rain water from roofs, down take pipes of at least 100 mm diameters should be used. Proper slopes should be given to roof towards down take pipe. These pipes should be fixed at 10 to 15 mm below the roof surface so that rain water is directed to the down take pipe easily.

The sanitary fittings are to be connected to stone ware pipes with suitable traps and chambers. Stone ware pipes are then connected to underground drainage of municipal lines or to the septic tank.

Many carpentry works are required for building service. They are in the form of showcases, cupboards, racks etc.

Electric supply is essential part of building services. The building should be provided with sufficient points for supply of lights, fans and other electric gadgets.

## 6.2 BASIC REQUIREMENTS OF A BUILDING

The planning and construction of a building should be aimed at fulfilling the following requirements:

1. Strength and stability
2. Dimensional stability
3. Resistance to dampness
4. Resistance to fire
5. Heat insulation
6. Sound insulation
7. Protection against termite attack
8. Durability
9. Security against burglary
10. Lighting and ventilation
11. Comforts and convenience
12. Economy.

1. **Strength and Stability:** Building should be capable of transferring the expected loads in its life period safely to the ground. Design of various structural components like slabs, beams, walls, columns and footing should ensure safety. None of the structural components should buckle, overturn and collapse.

2. **Dimensional Stability:** Excessive deformation of structural components give a sense of instability and result into crack in walls, flooring etc. All structural components, should be so designed that deflections do not exceed the permissible values specified in the codes.

3. **Resistance to Dampness:** Dampness in a building is a great nuisance and it may reduce the life of the building. Great care should be taken in planning and in the construction of the building to avoid dampness.

4. **Resistance to Fire:** Regarding achieving resistance to fire, the basic requirements laid down in the codes are:

- (a) the structure should not ignite easily.
- (b) building orientation should be such that spread of fire is slow.
- (c) In case of fire, there should be means of easy access to vacate building quickly.

5. **Heat Insulation:** A building should be so oriented and designed that it insulates interior from heat.

6. **Sound Insulation:** Buildings should be planned against outdoor and indoor noises.

7. **Protection from Termite:** Buildings should be protected from termites.

8. **Durability:** Each and every component of the building should be durable.

9. **Security against Burglary:** This is the basic need the owner of the building expects.

10. **Lighting and Ventilation:** For healthy and happy living natural light and ventilations are required. Diffused light and good cross ventilation should be available inside the building.

11. **Comforts and Conveniences:** Various units in the building should be properly grouped and integrated keeping in mind the comfort and convenience of the user.

12. **Economy:** Economy without sacrificing comfort, convenience and durability is another basic requirement of the building.

### 6.3 PLANNING

All buildings should be properly planned, keeping in view the various requirements of a good building. Except strength requirement, all other requirements of a good buildings are taken care at the stage of planning. Strength requirement is taken care during structural design of building components. However in planning the building by-laws of the statutory authorities should not be violated. Planning of the building is an art combined with science.

Principles of planning of buildings may be grouped into:

1. Orientation
2. Energy efficiency
3. Utility
4. Other requirements of the building. These principles are briefly explained in the articles 6.4 to 6.7.

### 6.4 PLANNING SUITABLE ORIENTATION

Orientation means setting out the plan of the building with respect to north-south and east-west directions to provide an opportunity to user to enjoy sun-shine and breeze when required and to avoid the same whenever not required. This is also known as planning the aspect of a building. Aspect means arrangement of doors, windows in the external wall to make good use of nature. This term has nothing to do with the architectural aspect of outlook of building. Kitchen should have eastern aspect to enjoy morning sunshine, means, kitchen should be located on the eastern side of the building to make use of morning sun rays. The following are the required aspects for various parts of the building in the northern hemisphere of earth:

- (a) Kitchen—eastern aspect.
- (b) Dining room—southern aspect to enjoy winter sun.
- (c) Drawing and living room—southern or south-eastern aspect to enjoy winter sun.
- (d) Bed rooms—western or south-western aspect to enjoy breez in summer.
- (e) Reading room, class room, stairs, northern aspect to enjoy diffused light.

The following suggestions should be kept in mind in the orientation of a building in India:

- (a) Place long walls towards north-south and short walls in east-west directions so as to reduce the area exposed to direct sun rays.

- (b) Provide verandah and balcony on east and west.
- (c) Provide chejjas on doors and windows on southern side to protect them from sun's rays.

## 6.5 PLANNING FOR ENERGY EFFICIENCY

A building should be planned in such a manner that it gives maximum day lighting, ventilation and heat insulation. If these requirements are fulfilled, requirement of electric energy comes down.

(a) **Light:** Natural light provides hygienic atmosphere. Light should not be glaring but it should be uniformly distributed. Providing windows and ventilators of appropriate size at suitable positions contributes a lot for natural lighting. For residential buildings window area to floor area should not be less than 1/10th while for school buildings it should not be less than 1/5th of floor area. For factory buildings north light trusses should be provided to get maximum diffused light.

(b) **Ventilation:** Ventilation is the circulation of the air in the building. Natural ventilation can be achieved by selecting and positioning of doors, windows and ventilators at suitable places. Always cross ventilations should be planned suitably. Provision of ventilators at roof level helps in driving out hot airs. In case it is not possible to achieve natural ventilation for any part of the building provide ordinary or exhaust fans.

(c) **Heat Insulation:** Thicker exterior walls provide insulation against heat. Proper ventilation also helps in achieving heat insulation. Sun shades provided to doors, windows and ventilators help in achieving heat insulation. In factories and assembly halls height should be more to reduce temperature inside the building. The position of furnaces in the factories should be located away from the other parts of the factory. The openings should be provided at higher level in the wall to remove hot air.

## 6.6 PLANNING FOR SUITABLE UTILITY

Principles of planning for suitable utility are:

1. Roominess
2. Furniture Requirements
3. Groupings
4. Circulation.

1. **Roominess:** It refers to suitable proportioning of length, width and height of rooms in the building to get maximum benefit from the minimum dimensions. Length to width ratio should be 1.2 to 1.5. If it is nearly square lot of area is wasted for movement, while, it is more than 1.5, it gives the 'tunnel' effect. Doors for rooms should be properly located so that utility and privacy are maximum. Cupboards and lofts should be provided to increase roominess. Proper colours to wall and floor also give roominess effect. Light colour gives effect of more space.

2. **Furniture Requirements:** In planning residential, office, laboratory, hospital buildings positions of required furniture should be drawn and then room dimensions, positions of doors, windows,

wardsities etc. planned. In case of planning a hostel room for two students it may need centrally placed door while if it is for three students, it should be near the end of front wall. Positions of cots, study tables and cupboard should be drawn and room planned. In designing a living room, positions of sofa, chairs, T.V. show case etc. should be drawn and size of the room and positions of doors fixed. Availability of circulation area should be checked. Thus the furniture requirement influences the planning of a building to a great extent.

3. **Grouping:** Grouping means disposition of various rooms in the building for the convenience of users and their utility. A dining room should be close to the kitchen, white sanitary block should be away from kitchen, but convenient to bedrooms. In case of offices, administrative department is located centrally. In factories, various sections are located such that product moves in one direction to get finally assembled after least movement. In residential buildings grouping is to achieve comfort, privacy and efficiency while in the case of other buildings it is to achieve economical service.

4. **Circulation:** Circulation means the space to be provided for movement from room to room or floor to floor. Passages, lobbies, halls provided serve horizontal circulation while stairs and lifts serve vertical circulation. Within a room also a portion of it serve for circulation while some other portion serve for utility. The following points should be considered in planning circulation:

- (a) They should be straight.
- (b) They should be sufficient.
- (c) They should be sufficiently lighted and ventilated.
- (d) Stairs should be easily accessible to all the users.
- (e) Sanitary services should have access for every user through passage lobby.

## 6.7 PLANNING FOR MEETING OTHER REQUIREMENTS

Principle of planning involves planning for meeting the following requirements also:

1. Sanitary convenience
2. Prospects
3. Elegance
4. Flexibility
5. Privacy
6. Resistance to fire
7. Sound insulation
8. Protection from termite
9. Security against burglary
10. Economy
11. Provisions for future alterations.

1. **Sanitary Convenience:** Sanitary conveniences include provision of bathrooms, lavatories, urinals etc. Provision of these are not only necessities but statutory requirement also. These facilities should be located giving free access to all users. In these blocks, suitable slopes should be given to the floors to drain out water easily.

2. **Prospects:** It is about locating and selecting types of doors and windows so as to reveal pleasant features and conceal undesirable features of the buildings from a person viewing from outside.

3. **Elegance:** Elegance means general effect produced for a viewer from outside. It depends upon proper positioning of doors, windows, ventilators, chejjas, balconies etc. Elevations should be attractive. The width, height and the projections in the building contribute a lot for the elegance. Taj Mahal is an example famous for its elegance.

4. **Flexibility:** This aspect of planning means a room designed for a specific purpose should be possible to use for other purposes, if necessary. A study room may be planned for using as a guest room. If partition is provided between living room and dining room, it is possible to remove partition and use living room plus dining room for the family functions. If independent access is given to backyard from kitchen, backyard can be used for dinner functions. Thus in planning flexibility also should be considered.

5. **Privacy:** Planning should take care of privacy of one room from other room in a building as well as some parts of a building from neighbouring buildings and from streets. It is ensured by proper grouping of rooms and by suitably providing doors, windows and ventilators. Planning the entrance at appropriate position also contributes a lot in providing privacy.

6. **Resistance to Fire:** It may be noted that concrete and masonry (stone or brick) have better resistance to fire while steel and wood have lesser resistance. Hence reduce use of steel and wood in kitchen and bathrooms with electric heaters. Kitchen should be so located that if fire is caught it is directed away from the building by the wind rather than towards the building. In public buildings and assembly halls stair cases should be easily accessible and always more than one is provided.

7. **Sound Insulation:** Noise pollution can be reduced by suitable planning of the building. Some of them are:

- (a) Orienting the building suitably so that rooms are kept away from road side.
- (b) Using hollow blocks for the walls.
- (c) Plugging door and window openings tightly.
- (d) Using false ceilings.
- (e) By fixing water closet cisterns on outer walls instead on wall common to rooms.
- (f) By fixing water closet pan on a thin pad.
- (g) Holding pipes passing through walls and floors by insulated clips.

8. **Protection from Termite:** Building should be protected from termite attack by

- (a) Treating the foundation with chemicals at the time of construction.
- (b) Using well seasoned and well treated wood in the building.

9. **Security against Burglary:** By providing thicker walls, using stronger doors and windows in outer walls, security against burgling is improved. Providing grills to windows and additional shutters

to doors are some of the methods of improving security. Alarms fitted in walls, roofs also improve security of the buildings.

10. **Economy:** Economy without sacrificing comfort, conveniences and durability is another basic principle of planning a building. For this circulation area should be minimised. Materials should be so selected that maintenance cost is minimized.

11. **Provision for Future Expansion:** Building should be planned making suitable provision for future expansion. Some of the steps required for it are:

- (a) Improving elevations without dismantling any part during future expansion.
- (b) Extending building horizontally or vertically without damaging the existing building.
- (c) Improving the flooring.

## QUESTIONS

1. What are the basic components of a building? Discuss the main requirements of each part to fulfill its primary function.
2. Briefly explain the principles of building planning.
3. Define orientation of a building. Explain the various aspects of orientation.
4. Describe the principles of planning with respect to utility.
5. Write short notes on energy efficiency in planning of building.



# Foundations

The definition and functions of foundation have been given in chapter 6. In this chapter broad guidelines for fixing the dimensions of foundation are given and different types of foundations are explained.

## 7.1 DIMENSIONS OF FOUNDATION

Guidelines for minimum dimensions are given below:

(a) *Depth of Foundation*: For all types of foundations minimum depth required is calculated using Rankine's Formula:

$$H = \frac{p}{w} \left( \frac{1 - \sin \phi}{1 + \sin \phi} \right)^2$$

where  $p$  = safe bearing capacity of soil

$w$  = unit weight of soil

$\phi$  = angle of repose of soil.

However in any case it is not less than 0.9 m. Finding safe bearing of the soil is an expert's job, and it is found after conducting tests in field or in Laboratories. However general values for common soils are listed in Table 7.1.

**Table 7.1**

S. No.	Type of Soil	SBC in kN/m <sup>2</sup>
1.	Igneous rocks (granite, troy etc.)	3300
2.	Sedimentary rocks (sand, stone etc.)	1650
3.	Residual deposits, hard shale, cemented materials	900
4.	Soft rock, coarse sand	450
5.	Medium sand	250
6.	Fine sand	150

7.	Loose gravel or sand gravel	250
8.	Soft shale, hard clay	450
9.	Medium clay, readily indented with thumb nail	250
10.	Moist clay, clay and sand mixture	150
11.	Soft clay	100
12.	Black cotton soil, peat and made up of ground	to be found after investigations

(b) *Width of Foundation:* Width of wall foundations or size of column footing is determined by first calculating the expected load and then dividing that with SBC. Thus,

$$\text{Width of wall foundation} = \frac{\text{Load per unit length of wall}}{\text{S.B.C. of soil}}$$

$$\text{Area of column footing} = \frac{\text{Load carried by column}}{\text{S.B.C. of soil}}$$

## 7.2 CONVENTIONAL SPREAD FOOTINGS

This type of foundations are commonly used for walls and masonry columns. These foundations are built after opening the trenches to required depth. Such footings are economical up to a maximum depth of 3 m. As these foundations are suitable depth, they are grouped under *shallow foundations*.

Figure 7.1 shows a conventional spread footing for a wall and Fig. 7.2 shows it for a masonry column.

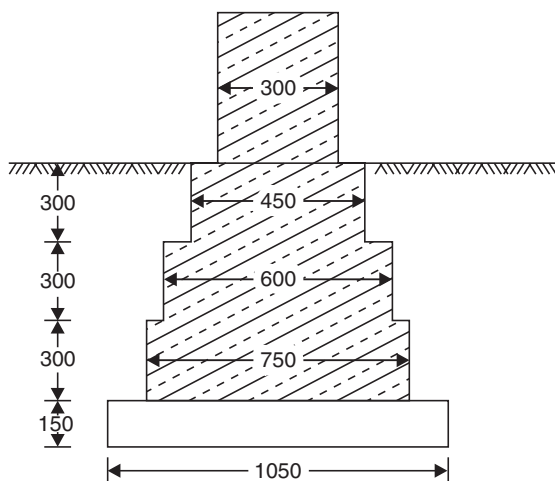


Fig. 7.1. Wall footing

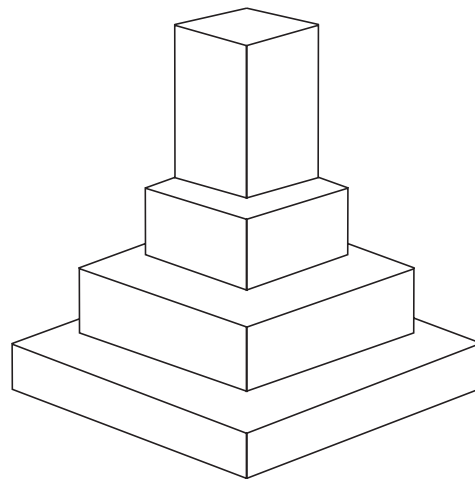


Fig. 7.2. Foundation for masonry pier

Before building these footing trenches are opened to required depth and the soil is rammed well. Then a plain concrete of mix 1 : 4 : 8 is provided. Its thickness varies from 150 to 200 mm. Over this bed, stone masonry footing is built. It is built in courses each course projecting 50 to 75 mm from the top course and height of each course being 150 to 200 mm. In case of wall footing the projections are only one direction while in case of columns, they are in both directions. The projection of bed concrete from the lowest course of foundation masonry is usually 150 mm.

### 7.3 R.C.C. FOOTINGS

There are mainly two types of R.C.C. footings:

1. One way reinforced footings.
2. Two way reinforced footings.

1. **One Way Reinforced Footing:** These footings are for the walls. In these footings main reinforcements are in the transverse direction of wall. In longitudinal directions there will be only nominal reinforcement.

2. **Two Way Reinforced Footings:** For columns two way reinforced footings are provided. The following types of the footings are common:

(i) **Isolated Column Footings:** If separate footings are provided for each column, it is called isolated column footing. Figure 7.3 shows a typical isolated column footing. The size of footing is based on the area required to distribute the load of the columns safely over the soil. These footings are provided over a 100 to 150 mm bed concrete. Required reinforcements and thickness of footing are found by the design engineers. Thickness may be uniform or varying.

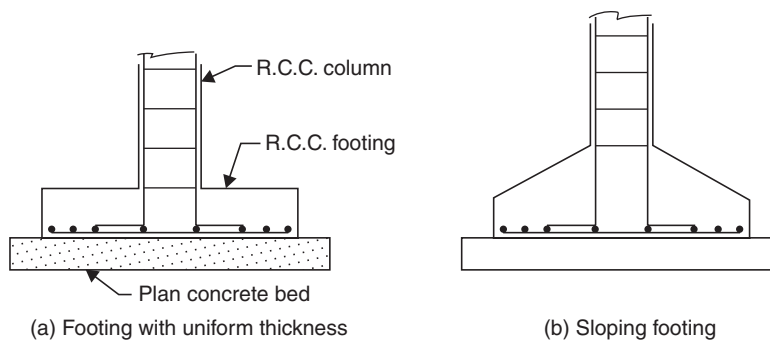


Fig. 7.3. Isolated R.C.C. footing

(ii) **Combined Footings:** Common footings may be provided for two columns. This type of footing is necessary when a column is very close to the boundary of the property and hence there is no scope to project footing much beyond the column face. Figure 7.4 shows a typical combined footing. The footing is to be designed for transferring loads from both columns safely to the soil. The two columns may or may not be connected by a strap beam.

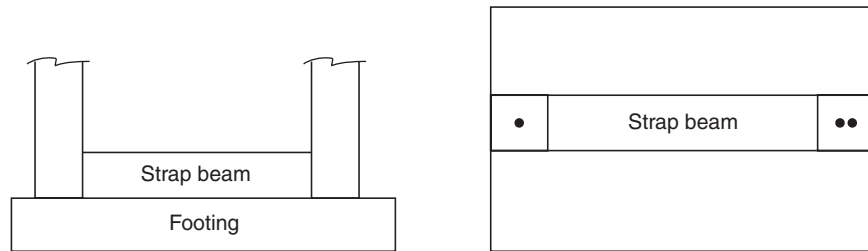


Fig. 7.4. Combined footing [Strap beam may or may not be provided]

(iii) **Continuous Footings:** If a footing is common to more than two columns in a row, it is called continuous footing. This type of footing is necessary, if the columns in a row are closer or if SBC of soil is low. Figure 7.5 shows this type of footing.

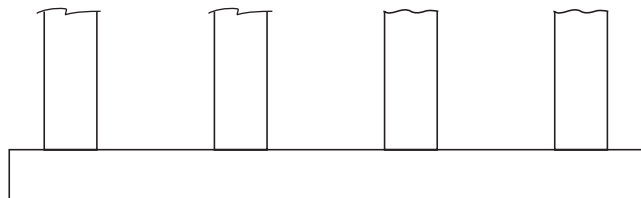


Fig. 7.5. Continuous footing

(iv) **Mat Footing/Raft Footing:** If the load on the column is quite high (Multistorey columns) or when the SBC of soil is low, the sizes of isolated columns may work out to be to such an extent that they overlap each other. In such situation a common footing may be provided to several columns as shown in Fig. 7.6. Such footings are known as raft footings. If the beams are provided in both directions over the footing slab for connecting columns, the raft foundations may be called as grid foundation also. The added advantage of such footing is, settlement is uniform and hence unnecessary stresses are not produced.

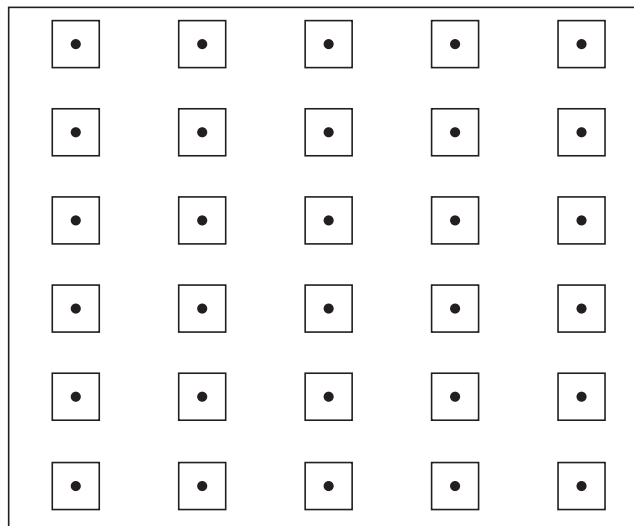


Fig. 7.6. Raft foundation

## 7.4 GRILLAGE FOOTING

High rise buildings are built with steel columns encased in concrete. Such columns carry very heavy load and hence they need special foundations to spread the load to a larger area of soil. Grillage foundation is one such special foundation. It consists of one tier or more tiers of I-sections steel beams. Figure 7.7 shows a typical two tier grillage foundation. Top tier consists of less number but large size steel section while lower tier consists of larger number but smaller size steel sections. Column load is transferred to the top tier through a base plate. The grillage beams are unpainted and are encased in concrete with minimum cover of 100 mm beyond the edges of steel sections. A minimum clear space of 75 mm should be maintained between the flanges of adjacent grillage beams so that concreting can be made properly. To maintain spacing, pipe separators are used.

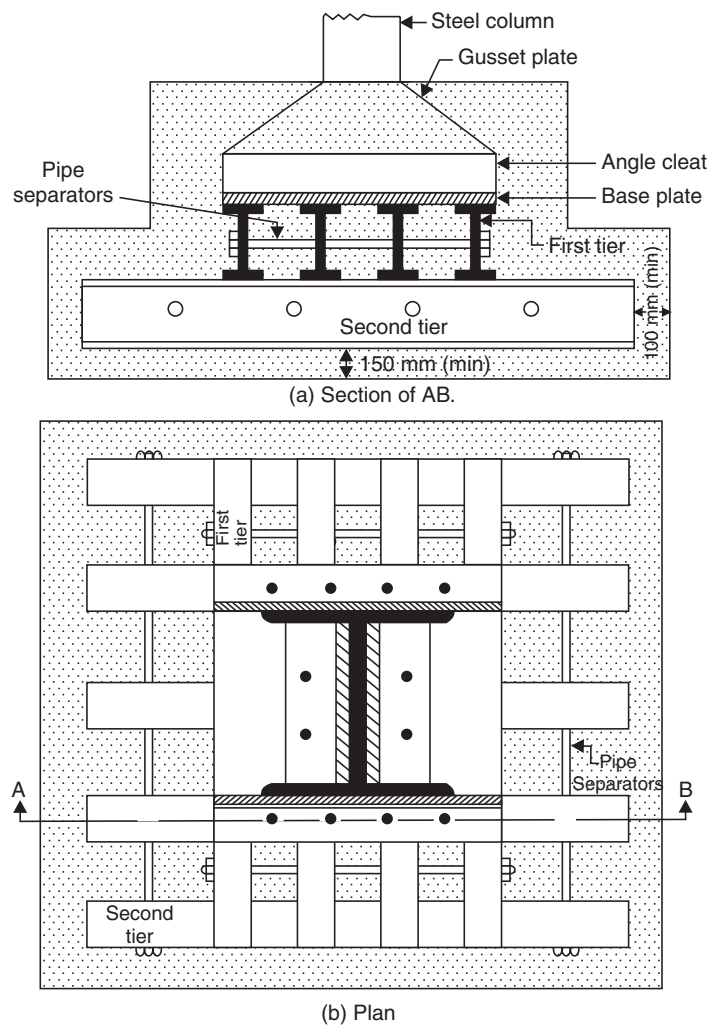


Fig. 7.7. Grillage foundation

### 7.5 ARCH FOUNDATION

Inverted arch foundations are provided in the places where the SBC of the soil is very poor and the load of the structure is through walls. In such cases inverted arches are constructed between the walls. End walls should be sufficiently thick and strong to withstand the outward horizontal thrust due to arch action. The outer walls may be provided with buttress walls to strengthen them. Figure 7.8 shows a typical inverted arch footing.

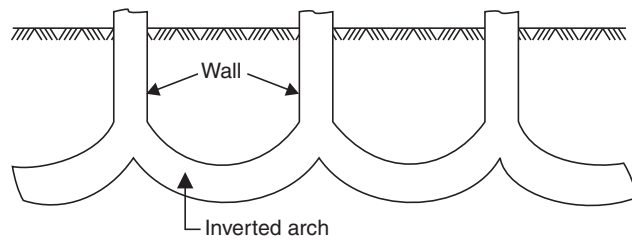


Fig. 7.8. Inverted arch footing

### 7.6 PILE FOUNDATIONS

These foundations are known as deep foundations. A pile is a slender column made of wood, concrete or steel. A pile is either driven into the soil or formed in situ by excavating a hole and then filling it with concrete. A group of piles are driven to the required depth and are capped with R.C.C. slab, over which super structure is built. The pile transfer the load to soil by friction or by direct bearing, in the latter case, piles being taken up to hard strata. This type of foundations is used when top soil is not capable of taking the load of the structure even at 3–4 m depth.

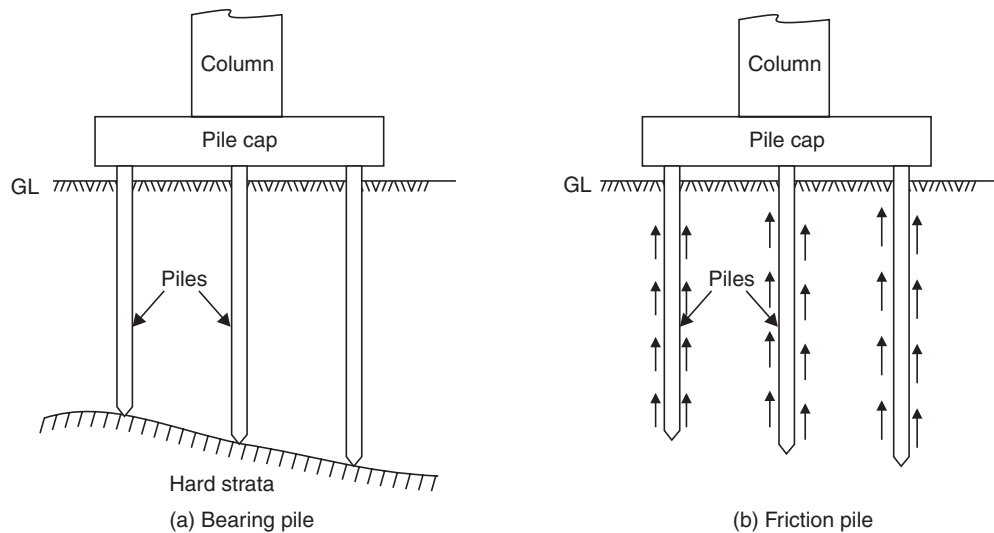


Fig. 7.9. Pile foundations

Pile foundations are classified according to the materials used and also on the nature of load transfer.

#### Classification According to Materials Used:

Piles may be classified as:

- (a) Timber piles
- (b) Concrete piles
- (c) Steel piles and
- (d) Composite piles.

(a) **Timber piles:** Circular seasoned wood can be used as piles. Their diameter may vary from 200 mm to 400 mm. Similarly square piles of sizes 200 mm to 400 mm are also used. The length of timber pile should not be more than 20 times its lateral dimension. The bottom of the pile is sharpened and is provided with iron shoe, so that it can be driven in the ground easily by hammering. These piles should be always kept below water table; otherwise alternating wet and dry condition cause the decay. These piles are cheap and can be easily driven rapidly. The main disadvantage is their load carrying capacity is low and are likely to be damaged during driving in the soil.

(b) **Concrete piles:** These piles may be further classified as precast piles and cast in situ piles.

*Precast piles* are reinforced with steel and are manufactured in factories. The cross-section diameter/dimension varies from 200 mm to 500 mm. Square, circular and octagonal sections are commonly used. The length of piles may be up to 20 m. They are provided with steel shoe at the lowest end. These piles can carry fairly large loads. These piles are highly resistant to biological and chemical actions of the soil. The disadvantage of these piles is they need more time to manufacture and are heavy to handle.

Figure 7.10(a) and (b) show concrete piles.

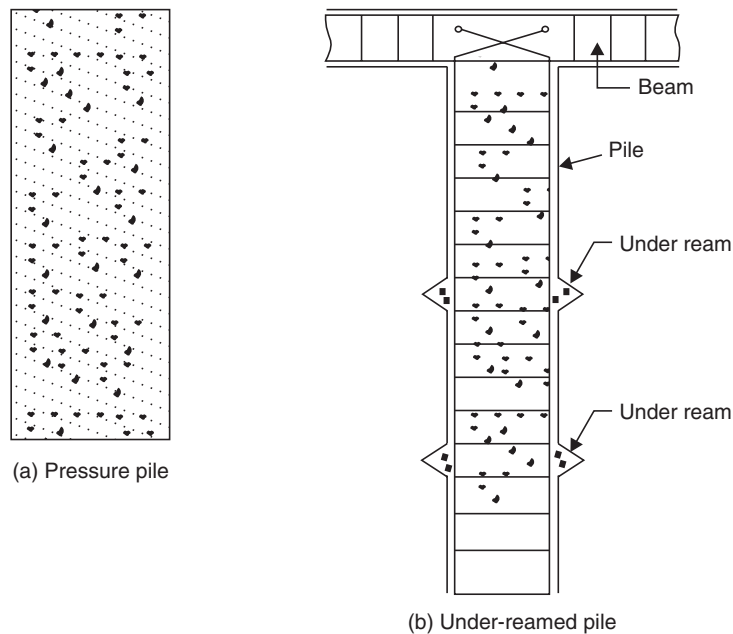


Fig. 7.10. Cast in situ concrete piles

*Cast in situ concrete piles* are formed first by boring the holes in the soil and then concreting them. Concreting is usually made using casing tubes. If the hole is filled with only plain concrete it is pressure pile. The load carrying capacity of the piles may be increased by providing enlarged base.

The reinforcement caging may be inserted in the bored holes and to increase load carrying capacity one or two under reams may be formed. After that concreting may be carried out. Such piles are known as under reamed piles. These piles are provided at regular interval of 2 to 4 m and capping beam is provided over them.

(c) **Steel Piles:** A steel pile may be a rolled steel I sections, tubes or fabricated in the form of box. These piles are mostly used as bearing piles since surface available for friction is less and also the coefficient of friction is less. If tubes are used the soil inside the tube is driven out by compressed air and concrete is filled. These piles are very useful for driving close to existing structures since they disturb the soil least.

(d) **Composite Piles:** Composite piles may be of concrete and timber or of concrete and steel. Wooden piles should not be subjected to alternating wet and dry conditions. Hence they are preferred for the portion below water table. The portion above water table are built with cast in situ concrete piles.

If the required length of steel piles is less than the depth of pile, many times upper portions are built with concrete. Thus steel and concrete composite piles are sometimes used.

#### **Classification of Piles According to Load Transfer:**

According to the load transfer to the soil piles may be classified as

- (a) Bearing piles and
- (b) Friction piles.

Bearing piles rest on hard strata and transfer the load by bearing. Such piles are preferred. These piles are used if the hard strata is available at reasonable depth.

Friction piles transfer the load to the soil by the friction between soil and the pile. Such piles are used if hard strata is not available to a considerable depth. The friction developed is to be properly assessed before deciding the length of the pile. The surface of such piles is made rough to increase the skin friction so that required length of pile is reduced.

## **7.7 FOUNDATIONS IN BLACK COTTON SOIL**

Black cotton soil swells during rainy season and cracks in summer due to shrinkage. These shrinkage cracks are 100 mm to 150 mm wide and 0.5 m to 2 m deep. Swelling creates upwards pressure on the structure and shrinkage creates downward pull. It results into cracks in foundations wall and roof. Hence foundation in black cotton soil need special care.

In case black cotton soil is only to a depth of 1.0 m and 2.0 m it is economical to remove entire black cotton soil from the site and build the foundation on red soil. Apart from this black cotton soil should be removed from the sides of the foundation and filled with sand and gravel.



In case the depth of black cotton soil is more, the following type of foundation may be provided

1. Strip or pad foundation
2. Pier foundation with arches and
3. Under reamed pile foundation.

1. **Strip or Pad Foundation:** Strip foundation are for walls while pad foundations are for columns. In these foundation the attempt is to keep black cotton soil from foundation by interposing layers of sand and gravel. These foundations should be constructed during dry season. Suitable plinth protection should be made around external walls with its slops away from the wall, so that moisture do not penetrate the foundation during rainy season. Figure 7.11 shows such foundations.

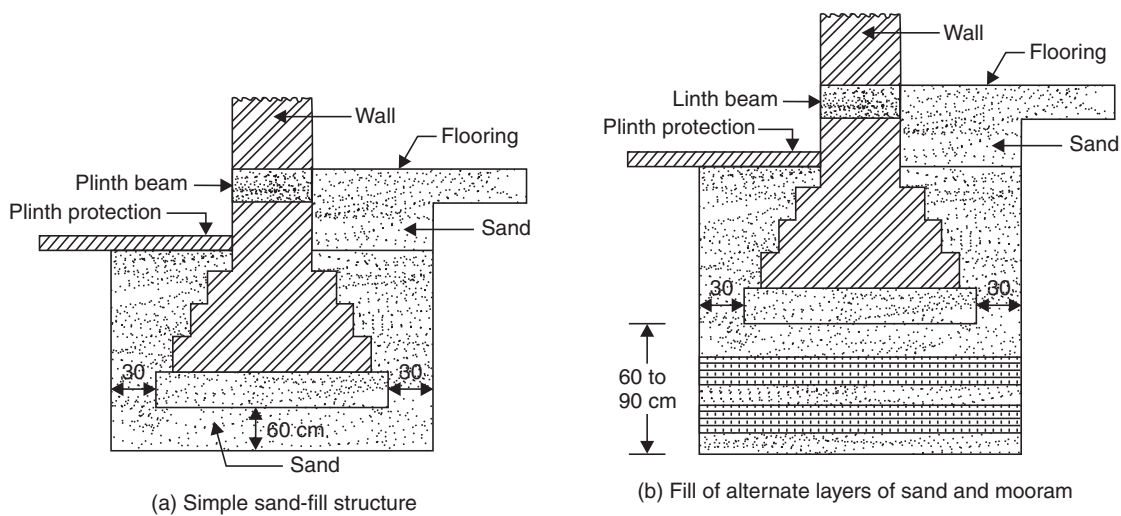


Fig. 7.11. Strip or Pad foundation

2. **Pier Foundation with Arches:** A pier is a vertical columns of relatively larger cross-section than piles. For walls carrying heavy loads, piers are dug at regular intervals and filled with plain concrete. These piers are taken up to good bearing strata. Then the piers are connected by concrete or masonry arch. Over these arches regular masonry is built. Figure 7.12 shows a typical pier foundation with arches.

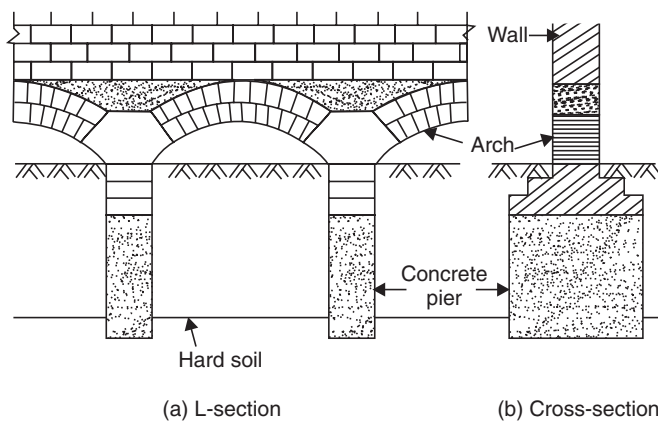


Fig. 7.12. Pier foundation with arches

*Under Reamed File Foundations:* Under reamed piles are bored and then concreted at the sites. Their length may vary from 3 to 6 m. They are provided with reams and reinforcement. The pile spacing varies from 2 to 4 m. The top of piles are provided with capping beams over which walls are built. [Ref. Fig. 7.10 (b)].

## QUESTIONS

1. Briefly explain how depth and width of foundations are fixed.
2. With neat sketches explain conventional spread footing.
3. Neatly sketch the following types of R.C.C. footings and explain the situations in which they are used
  - (a) Isolated column footings
  - (b) Combined footings
  - (c) Mat foundations.
4. What is grillage footing? When do you go for such footings? Neatly sketch a typical grillage footing.
5. Write short notes on
  - (a) Arch foundations
  - (b) Foundation in black cotton soil
  - (c) Pile foundations.

## Super Structures

The portion above the ground level and below the ground floor level is known as plinth. The portion above the ground floor level is known as super structure. It includes walls, columns, beams, floors, roofs, doors, windows, lintels, staircases etc. In this chapter types of super structures based on the method of load transfer is first presented and then the various components are discussed giving their functions and types.

### 8.1 TYPES OF SUPER STRUCTURES BASED ON THE METHOD OF LOAD TRANSFER

On this basis there are two types

1. Load Bearing Structures
2. Framed Structures.

**1. Load Bearing Structures:** In this type of structure the load on the structure is transferred vertically downward through walls. Loads from roof and floors gets transferred to wall and then wall has to transfer these loads as well as self weight. Such constructions are used in residential buildings where dimension of rooms is less. Residential buildings up to ground + 2 floors can be built economically with such structures.

**2. Framed Structures:** In this type of structures a frame work of columns, beams and floors are built first. Then walls are built to partition the living area. The walls are subjected to self-weight only. This type of super structures are required when number of stories in a building is more and also when larger areas are to be covered free from walls.

Table 8.1 shows the comparison between R.C.C. framed structures and load bearing structures.

**Table 8.1.** Comparison between load bearing and framed structures

<i>S. No.</i>	<i>Load Bearing Structure</i>	<i>Framed Structure</i>
1.	Cost is less.	Cost is more.
2.	Suitable up to three stories.	Suitable for any number of stories.
3.	Walls are thicker and hence floor area is reduced.	Walls are thinner and hence more floor area available for use.

4.	Slow construction.	Speedy construction.
5.	Not possible to alter the position of walls, after the construction.	Position of walls may be changed, whenever necessary.
6.	Resistance to earthquake is poor.	Resistance to earthquake forces is good.

## 8.2 WALLS

Walls are built to partition living area into different parts. They impart privacy and protection against temperature, rain and theft. Walls may be classified as

1. Load bearing walls
2. Partition walls.

**1. Load Bearing Walls:** If beams and columns are not used, load from roof and floors are transferred to foundation by walls. Such walls are called load bearing walls. They are to be designed to transfer the load safely. The critical portion of the walls are near the openings of doors and windows and the positions where concrete beams rest.

Minimum wall thickness used is 200 mm. It is also recommended that the slenderness ratio of wall defined as ratio of effective length or effective height to thickness should not be more than 27. The effective height and effective length of a wall may be taken as shown in tables 8.2 and 8.3 respectively.

**Table 8.2.** Effective height of walls in terms of actual height H

<i>S. No.</i>	<i>End Condition</i>	<i>Effective Height</i>
1.	Lateral as well as rotational restraint	0.75 H
2.	Lateral as well as rotational restraint at one end and only lateral restraint at other	0.85 H
3.	Lateral restraint but no rotational restraint at both ends	1.0 H
4.	Lateral and rotational restraint at one end and no restraint at other ends (compound walls, parapet walls etc.).	1.5 H

**Table 8.3.** Effective length of walls of length L

<i>S. No.</i>	<i>End Condition</i>	<i>Effective Length</i>
1.	Continuous and supported by cross walls	0.8 L
2.	Continuous at one end and supported by cross walls at the other end	0.9 L
3.	Wall supported by cross walls at each end	1.0 L
4.	Free at one end and continuous at other end	1.5 L
5.	Free at one end and supported by cross wall at other end	2.0 L

**2. Partition Walls:** In framed structures partition walls are built to divide floor area for different utilities. They rest on floors. They do not carry loads from floor and roof. They have to carry only self-weight. Hence normally partition walls are thin. Table 8.4 shows the differences between load bearing walls and partition walls. Depending upon the requirement these walls may be brick partition, clay block partition, glass partition, wood partition, and aluminium and glass partition.

**Table 8.4.** Differences between load bearing and partition walls

<i>S. No.</i>	<i>Load Bearing Walls</i>	<i>Partition Walls</i>
1.	They carry loads from roof, floor, self-weight etc.	They carry self-weight only.
2.	They are thick and hence occupy more floor area.	These walls are thin and hence occupy less floor area.
3.	As the material required is more, the construction cost is more.	As the material required is less, the construction cost is less.
4.	Stones or bricks are used for the construction.	Stones are not used for the construction of partition walls.

### 8.3 STONE MASONRY

Masonry means construction of buildings using building blocks like stone, bricks, concrete blocks etc. Masonry is used for the construction of foundation, plinth, walls and columns. Mortar is the binding material for the building blocks. In this article different types of stone masonry used are explained and points to be observed while supervising stone masonry works are listed.

#### Types of Stone Masonry

Mainly there are two types of stone masonry:

1. Rubble Masonry
2. Ashlar Masonry.

**1. Rubble Masonry:** In this type of constructions stones of irregular sizes and shapes are used. To remove sharp shapes they may be hammered. The rubble masonry may be *coursed* or *uncoursed* [Fig. 8.1 and 8.2]. In *uncoursed rubble masonry* the wall is brought to level at every 300 mm to 500 mm. The mortar consumed in these construction is more. Course rubble masonry is used for the construction of public and residential buildings. Uncoursed rubble masonry is used for the construction of foundations, compound walls, garages, labour quarters etc. A skilled mason may arrange the facing stones in *polygonal shapes* to improve the aesthetic of the wall.

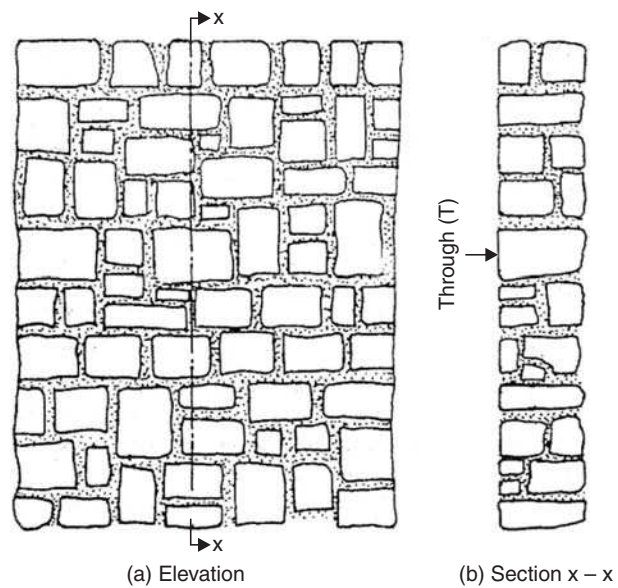


Fig. 8.1. Uncoursed rubble masonry

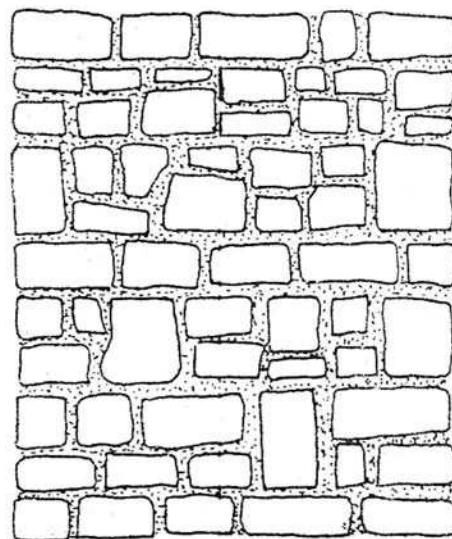


Fig. 8.2. Coursed rubble masonry

- 2. Ashlar Masonry:** In this type of masonry stones are dressed to get suitable shapes and sizes. The height of the stones varies from 250 mm to 300 mm. The length should not exceed three times the height. The dressing of the stone need not be very accurate on all sides. Usually good dressing is made on facing side. In such construction mortar consumption is less compared to rubble masonry.

There are different types of ashlar masonry depending upon the type of dressing such as Ashlar fine dressed, Ashlar rough dressed, Ashlar rock or quarry faced, Ashlar facing, Ashlar chamfered etc. Figure 8.3 show some of such masonry.

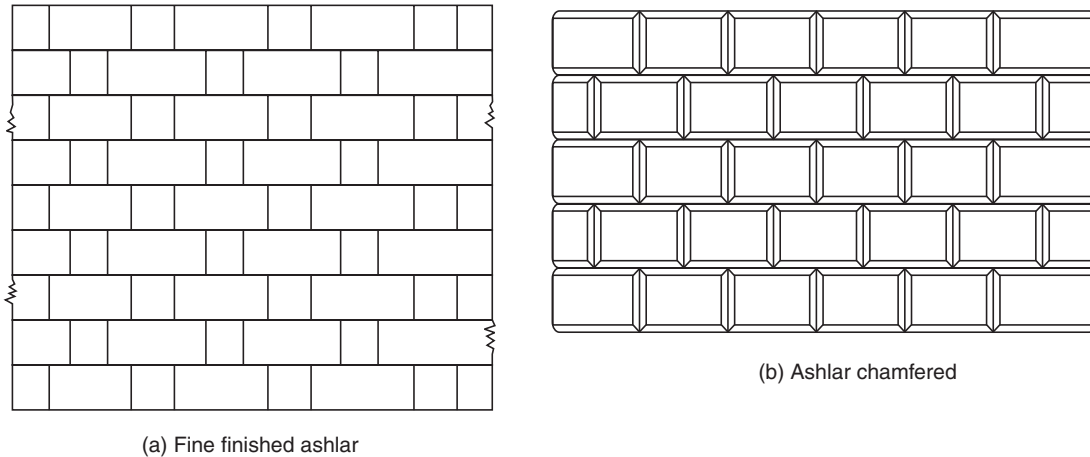


Fig. 8.3. Ashlar masonry

### Supervision of Stone Masonry Construction

The following points should be kept in mind in supervising stone masonry work:

1. Hard and durable stones, free from defects like flaws, cavities veins etc. should be used.
2. Dressing of the stones should be as per the requirement.
3. Stones should be properly wetted before they are used so as to avoid sucking of water from mortar.
4. Stones should be laid on their natural bed.
5. Facing and backing faces should be laid neatly and levelled and checked with wooden template.
6. The heart of masonry should be filled with stone chips and mortars. To thick mortar joints should be avoided.
7. Verticality of the wall should be frequently checked with plumb-bob.
8. Mortars with correct proportion of sand and cement should be used.
9. Continuous vertical joints should be avoided.
10. Through stones should be used within 1.5 m distances.
11. The height of masonry should be raised uniformly.
12. Under the beams, trusses, sills etc large flat stones should be used.
13. Before continuing work, the masonry built on previous day should be well cleaned and freed from loose particles.
14. Curing should be done properly for 2 to 3 weeks.

## 8.4 BRICK MASONRY

Brick masonry is built with bricks bonded together with mortar. For temporary sheds mud mortar may be used but for all permanent buildings lime or cement mortars are used.

The various types of bonds generally used in brick masonry are

1. Stretcher bond
2. Header bond
3. English bond and
4. Flemish bond.

**1. Stretcher Bond:** A stretcher is the longer face of the brick as seen in the elevation. In the brick of size 190 mm × 90 mm × 90 mm, 190 mm × 90 mm face is the stretcher. In stretcher bond masonry all the bricks are arranged in stretcher courses as shown in Fig. 8.4. However care should be taken to break vertical joints. This type of construction is useful for the construction half brick thick partition wall.

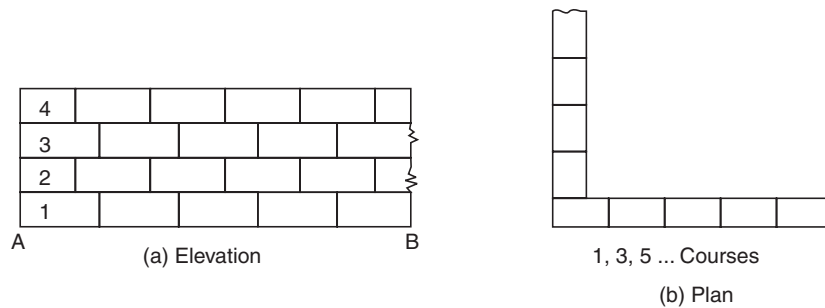


Fig. 8.4. Stretcher bond

**2. Header Bond:** A header is the shorter face of the brick as seen in the elevation. In a standard brick it is 90 mm × 90 mm face. In header bond brick masonry all the bricks are arranged in the header courses as shown in Fig. 8.5. This type of bond is useful for the construction of one brick thick walls.

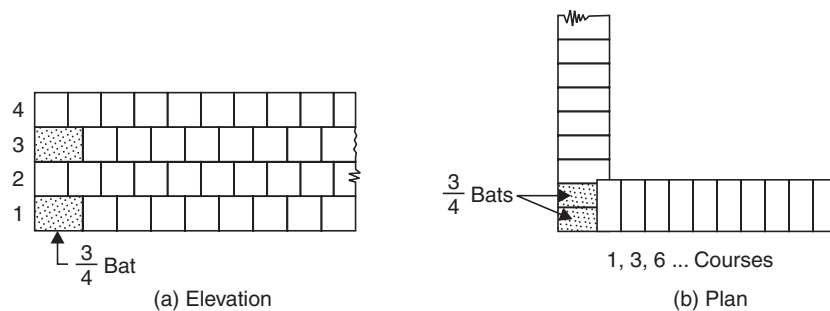
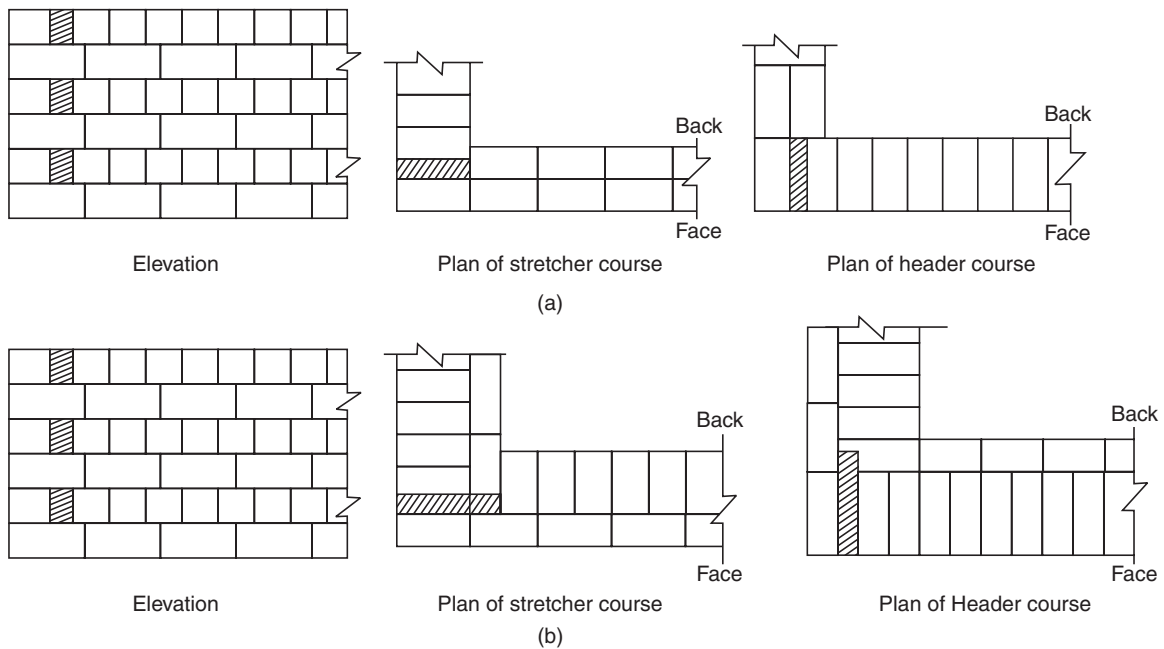


Fig. 8.5. Header bond



**3. English Bond:** In this alternate courses consist of headers and stretchers. This is considered to be the strongest bond. Hence it is commonly used bond for the walls of all thicknesses. To break continuity of vertical joints a brick is cut lengthwise into two halves and used in the beginning and end of a wall after first header. This is called queen closer. [Ref. Fig. 8.6]. Figure 8.6 shows typical one brick and one and half brick thick wall with English bond.



**Fig. 8.6.** English bond

**4. Flemish Bond:** In this type of bond each course comprises of alternate header and stretcher [Fig. 8.7]. Alternate courses start with stretcher and header. To break the vertical joints queen closers are required, if a course starts with header. Every header is centrally supported on the stretcher below it.

Flemish bonds may be further classified as

- (a) Double Flemish Bond
- (b) Single Flemish Bond.

In case of *double flemish bond*, both faces of the wall have flemish look, *i.e.* each course consist of alternate header and stretcher, whereas *single flemish bond* outer faces of walls have flemish look whereas inner faces have look of English bond [Fig. 8.7 (a), (b)].

Construction of flemish bond needs greater skill. It gives more pleasing appearance. But it is not as strong as English bond. If only pointing is to be used for finished wall, flemish bond may be used to get good aesthetic view. If plastering is going to be used, it is better to use English bond.

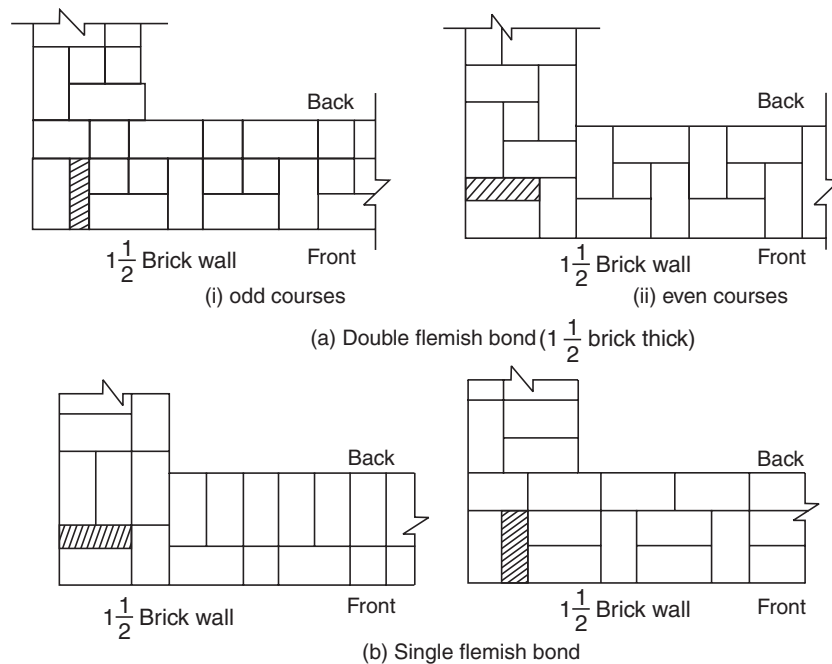


Fig. 8.7. Flemish bond

### Points to be Observed in Supervising Brick Masonry Constructions

The following points should be observed in the construction of brick masonry:

1. Use bricks of good quality with uniform colour, well burnt, with exact shape and size.
2. Before using the bricks in masonry, they should be soaked in water for 2 hours so that bricks do not absorb water from the mortar.
3. Bricks should be laid with the frog pointing upward.
4. Construction of brick wall should start from the end or corner.
5. Brick courses should be perfectly horizontal.
6. Verticality of the wall should be ensured by frequently checking with plumb-bob.
7. Mortar used should be as per specification.
8. Whenever work is stopped brick masonry should be left with toothed end.
9. Use of brick bats should be avoided.
10. Walls should be raised uniformly. In no case difference between adjoining walls be more than 1 m. In a day no wall should be raised by more than 1.5 m.
11. To get proper key for plastering or pointing, the face joints should be raised to a depth of 12 to 20 mm, when the mortar is green. If plastering or pointing is not to be provided, face joints should be stuck flush and finished neatly.
12. Holdfasts for doors and windows should be embedded in brick masonry with cement mortar or concrete, at the time of constructing the wall itself.

13. Brick masonry should be regularly cured for 2 weeks.
14. For carrying out brick work at higher levels, only single scaffolding should be used.

### **Advantages and Disadvantages of Brick Masonry Over Stone Masonry**

#### *Advantages:*

1. Since shape and size of bricks are uniform, it do not need skilled labour for the construction.
2. Bricks are light in weight and hence handling them is easy.
3. Bricks are easily available around cities and their transportation cost is less because their weight is less. Stones are to be brought from quarries which are located only at few places.
4. It is possible to use all types of mortar in brick masonry. For unimportant buildings even mud mortar can be used.
5. Thinner walls can be constructed with bricks but it is not so with stones.
6. It is easy to form openings for doors and windows.
7. Dead load of brick masonry is less.
8. In brick masonry mortar joints are thin and hence construction cost is reduced considerably.
9. Brick masonry has better fire and weather resistance compared to stone masonry.

#### *Disadvantages:*

1. Strength of brick masonry is less than that of stone masonry.
2. Durability of brick masonry is less.
3. Brick masonry needs plastering and plastered surface needs colour washing. Stone masonry don't need them and hence maintenance cost is more in brick masonry.
4. Brick masonry absorbs water and there are possibility of dampness. There is no such problem in stone masonry.
5. More architectural effects can be given in stone masonry compared to that in brick masonry.
6. Stone masonry gives massive appearance and hence monumental buildings are built in stone masonry.

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## **8.5 PLASTERING**

Applying mortar coats on the surfaces of walls, columns, ceiling etc. to get smooth finish is termed as plastering. Mortar used for plastering may be lime mortar, cement mortar or lime-cement mortar. Lime mortar used shall have fat lime to sand ratio of 1 : 3 or 1 : 4. If hydraulic lime is used mix proportion (lime: sand) is 1 : 2. Cement mortar of 1 : 4 or 1 : 6 mix is very commonly used for plastering, richer mix being used for outer walls. To combine the cost effectiveness of lime mortar and good quality of cement mortar many use lime-cement mortar of proportion (cement : lime : sand) of 1 : 1 : 6 or 1 : 1 : 8 or 1 : 2 : 8.

The *objective* of plastering are:

1. to conceal defective workmanship
2. to give smooth surface to avoid catching of dust.

3. to give good look.
4. to protect the wall from rain water and other atmospheric agencies.
5. to protect surfaces against vermit.

**Requirement of good plaster are:**

1. It should adhere to the background easily.
2. It should be hard and durable.
3. It should prevent penetration by moisture
4. It should be cheap.

Lime mortar is usually applied in 3 coats while cement mortar is applied in two or three coats for the stone and brick masonry. For concrete surfaces cement mortar may be applied in two or three coats. For concrete building blocks many times only one coat of cement mortar is applied.

The first coat provides means of getting level surface. The final coat provides smooth surface. If three coats are used second coat is known as floating coat. The average thickness of first coat is 10 to 15 mm. Middle coat thickness is 6–8 mm. The final coat is just 2 to 3 mm thick. If single coat is used its thickness is kept between 6 to 12 mm. Such coats are used on concrete surfaces not exposed to rain.

## 8.6 POINTING

Instead of plastering entire surface of the masonry, special mortar finishing work is done to the exposed joints. This is called pointing. It consists of raking the joints to a depth of 10 mm to 20 mm and filling it with richer mortar mixes. In case of lime mortar pointing mix used is 1 : 2 and in case of cement mortar pointing mix used is 1 : 3. Pointing is ideally suited for stone masonry because stones are having attractive colours and good resistance to penetration by water. Pointing gives perfection to weaker part of masonry (*i.e.* to joints) and it adds to aesthetic view of the masonry.

The table 8.5 gives the comparison between plastering and pointing.

**Table 8.5.** Comparison between plastering and pointing

<i>S. No.</i>	<i>Plastering</i>	<i>Pointing</i>
1.	It is applied to entire surface.	It is provided only at exposed joints.
2.	It provides smooth surface.	It does not provide smooth surface.
3.	It conceals defective workmanship in the masonry construction.	It is used to expose beauty of well built masonry work.
4.	It provides a base for applying white/ colour washing.	White washing or colour washing are ruled out.

## 8.7 FLOORING

Purpose of flooring is to get a good hard, level and beautiful surface for living. The floors directly resting on the ground are known as ground floors while the floors of each storey are known as upper floors.

## Ground Floor

Apart from giving good finished surface, these floors should have good damp resistance. The ground surface is rammed well and a layer of red earth or sand is placed which is compacted. A layer of broken bricks, stones etc. is provided up to 150 mm below floor finish level and rammed. While ramming the surface is kept moist to get good compaction. Then 1 : 4 : 8 concrete of 100 to 150 mm thickness is provided as base course. Over this bed floor finish is laid.

The types of flooring used are:

- |                   |                    |
|-------------------|--------------------|
| 1. Mud and moorum | 2. Brick           |
| 3. Flag stone     | 4. Cement concrete |
| 5. Terrazo        | 6. Mosaic          |
| 7. Marble         | 8. Tiles           |
| 9. Timber         | 10. Rubber         |
| 11. P.V.C.        |                    |

1. **Mud and Moorum Flooring:** These floorings are used in low cost housing, specially in villages. Over the hard layer of earth filling mud or moorum layer is provided. The floor needs a thin wash of cow dung at least once a week.
2. **Brick Flooring:** This is also a cheap floor construction. It is commonly used in godowns and factories. Bricks are laid flat or on edges. Bricks of good quality should be used for the construction. Brick layer is provided on sand bed or on lean concrete (1 : 8 : 16) bed. In both cases joints are rendered flush and finished with cement mortar.
3. **Flag Stone Flooring:** Laminated sand stones or slates of 20 mm to 40 mm thick in the form of slabs of 300 mm × 300 mm or 450 mm × 450 mm or in the form of rectangles of size 450 mm × 600 mm are used as floor finishes. The stone slabs are laid on 20 to 25 mm thick mortar spread over concrete bed. The joints are to be finished with rich mortar.
4. **Cement Concrete Floors:** It is modestly cheap and durable floor and hence commonly used in residential, commercial and industrial buildings. It consists of two courses-base course and wearing coat. Base course is laid over well compacted soil. Its thickness is usually 75 mm to 100 mm. It consists of lean cement concrete mix (1 : 4 : 8) or lime concrete containing 40% of 1 : 2 lime mortar and 60% of coarse aggregate of 40 mm size. After base course is hardened wearing coat of 40 mm is laid. It consists of panels of 1 m × 1 m, 2 m × 2 m or 1 m × 2 m. Alternate panels are laid with 1 : 2 : 4 concrete using wooden, glass or asbestos strip separators of 1.5 mm to 2.0 mm thickness. To get good bond between base course and wearing coat cement slurry wash is given before laying wearing coat panels. After 3–4 days of laying of one set of panel, another alternate panels are laid. Top of these panels are finished by tamping the surface with wooden floats and tapping with trowels, till cement slurry appears on top. It needs curing for 7 to 14 days. To get good appearance many times red-oxide finishing coat is provided.
5. **Terrazo Flooring:** Terrazo finishing coat is applied over concrete flooring to get pleasing appearance. Terrazo finish consists of 75 to 80% of surface marble chips embedded in cement mortar.

Marble chips are mixed in cement in the proportion 1 : 1.25 to 1 : 2 and about 6 mm terrazo topping is laid. The top is tamped and rolled. Additional marble chips are spread during tamping to get proper distribution of marble chips on the surface. After drying it for 12 to 20 hours, it is cured for 2–3 days.

Then grinding is made in the following three steps:

Ist grinding—Using coarse grade (No. 60) carborundum stones.

IIInd grinding—Using medium grade (No. 120) carborundum stones.

IIIrd grinding—Using fine grade (No. 320) carborundum stones.

Plenty of water is used during grinding. After each grinding cement grout of cream-like consistency is applied and cured for 6–7 days. After final grinding and curing the floor is washed with plenty of water and then with dilute oxalic acid solution. Then floor is finished with polishing using machines and wax polish.

6. **Mosaic Flooring:** It consists of a finishing coat of small pieces of broken tiles of China glazed or of marble arranged in different patterns set in lime-surkhi or cement mortar. The base coarse is concrete flooring and on it 30 to 40 mm mortar layer is provided. On this mortar layer broken pieces of China glazed or marble are set to get different attractive patterns. After 20 to 24 hours of drying the top is rubbed with carborundum stone to get smooth and polished surface.
7. **Marble Flooring:** Marble slabs are cut to get marble tiles of 20 to 25 mm thickness. They are laid on floors similar to other tiles. With power driven machine surface is polished to get even and shining surface. This type of flooring is widely used in hospitals and temples.
8. **Tiled Flooring:** This is an alternative to terrazo flooring, used commonly used in residential, office and commercial buildings. Tiles of clay, cement or terrazo of standard sizes are manufactured in factories under controlled conditions. On the concrete base, 25 mm to 30 mm thick mortar is laid and these tiles are placed and pressed with trowel or wooden mallet. Before placing tiles care is taken to see that, neat cement slurry is applied to bottom side and sides of tiles to get good bond. Next day joints are cleaned of loose mortar and raked up to 5 mm depth. Then that is filled with coloured cement slurry to get uniform colour on the top surface. After curing for 7 days grinding and polishing is made as in the case of terrazo flooring.
9. **Timber Flooring:** Timber flooring are used in dancing halls and in auditoriums. Timber plates may be directly placed on concrete bed or may be provided over timber frame work. In latter case it is necessary to provide proper ventilation below the floor. This flooring is costly.
10. **Rubber Flooring:** Tiles or sheets of rubber with fillers such as cotton fibres, asbestos fibre or granulated cork are manufactured in variety of patterns and colours. These sheets or tiles may be fixed to concrete or timber floors. These floors are attractive and noise proof. However they are costly.
11. **P.V.C. Flooring:** Poly-Vinyl-Chloride (PVC) is a plastic which is available in different colour and shade. Nowadays tiles of this material are used widely. Adhesives are applied on concrete base as well as on bottom of PVC tiles. Then the tile is pressed gently with 5 kg wooden roller till the oozing of adhesive is seen. The oozed out adhesive is wiped and the floor is

washed with warm soap water. The floor finish is smooth, attractive and can be easily cleaned. However it is slippery and costly.

### Upper Floors

In olden days upper floors were made of *timber floors* or *steel joist and stone slabs*. For larger spans jack arch floorings were used. *Jack arch floor* consisted of I-section steel beams supported on walls and gap between I-sections beams filled with concrete arch. Figure 8.8 shows a typical jack arch flooring.

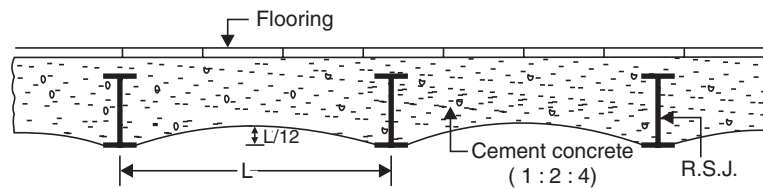


Fig. 8.8. Jack arch flooring

Nowadays *R.C.C. floors* are commonly used. It may consist of *only slab*, if span is less or it may be *beam and slab flooring*. In halls of hotels and assembly, many provide *flat slabs* i.e. slabs directly supported over columns. The columns are provided with widened portion called column head. They give elegant look to halls, particularly when the head room is high. R.C.C. floors need proper thickness and reinforcements. They are arrived at by structural design engineers. Figure 8.9 shows typical R.C.C. slabs.

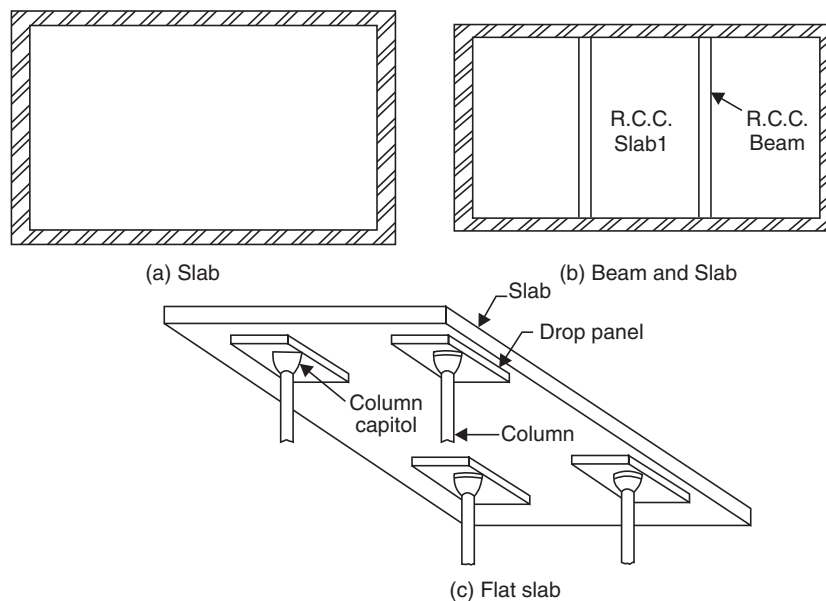


Fig. 8.9. R.C.C. floors

In R.C.C. concrete is used to resist compression and steel to resist tension. Hence the concrete in tension zone do not contribute in resisting the load. It just keeps the steel at required position. In *reinforced brick slab* an attempt is made to replace concrete in tension zone by bricks. It is better thermal efficient than solid concrete floors. Figure 8.10 shows a typical reinforced brick slab.

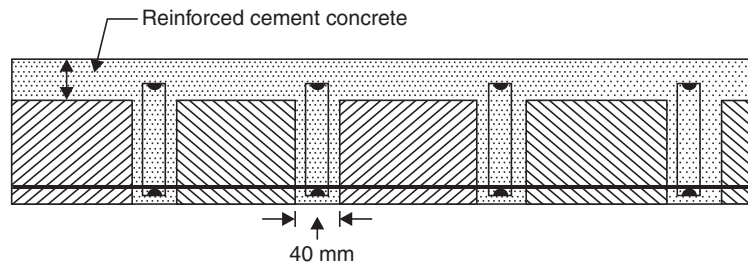


Fig. 8.10. Reinforced brick slab

In *ribbed or hollow tiled flooring*, the concrete in tension portion is replaced by hollow tiles. Figure 8.11 shows a typical floor of this type.

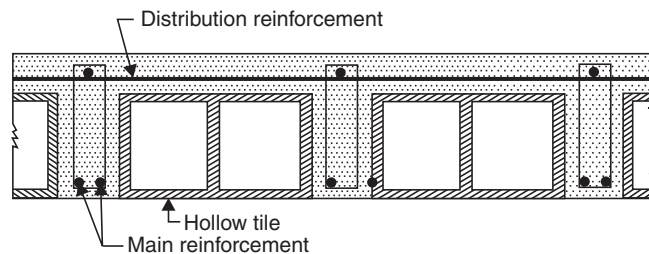


Fig. 8.11. Ribbed or Hollow tiled flooring

In precast concrete floor panels may be used which helps in avoiding form works, storing of sand, coarse aggregates etc. at the site and also curing. Factories manufacture these units which are to be placed over supports in the structure. Figure 8.12 shows the cross-section of a typical precast floor unit. These units are available in 0.25 m widths and in various spans. Interlocking grooves are provided on the sides to get tight connection with adjoining units.

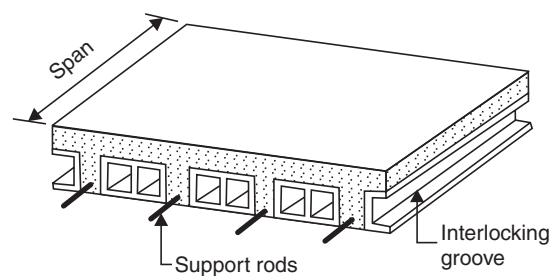


Fig. 8.12. Precast floor unit

## 8.8 ROOF

Roof is the upper most portion of the building which protects the building from rain, wind and sun. Various types of roofs used may be divided broadly into three types:

1. Flat roofs
2. Pitched roofs
3. Shells and folded plates.



Flat roofs are used in plains where rainfall is less and climate is moderate. Pitched roofs are preferred wherever rainfall is more. Shells and folded plate roofs are used to cover large column free areas required for auditoriums, factories etc. Brief description of these roofs is presented below:

- 1. Flat Roofs:** These roofs are nearly flat. However slight slope (not more than  $10^\circ$ ) is given to drain out the rain water. All types of upper storey floors can serve as flat roofs. Many times top of these roofs are treated with water proofing materials-like mixing water proofing chemicals in concrete, providing coba concrete. With advent of reliable water proofing techniques such roofs are constructed even in areas with heavy rain fall.

The *advantages* of flat roofs are:

- (a) The roof can be used as a terrace for playing and celebrating functions.
- (b) At any latter stage the roof can be converted as a floor by adding another storey.
- (c) They can suit to any shape of the building.
- (d) Over-head water tanks and other services can be located easily.
- (e) They can be made fire proof easily compared to pitched roof.

The *disadvantages* of flat roofs are:

- (a) They cannot cover large column free areas.
- (b) Leakage problem may occur at latter date also due to development of cracks. Once leakage problem starts, it needs costly treatments.
- (c) The dead weight of flat roofs is more.
- (d) In places of snow fall flat roofs are to be avoided to reduce snow load.
- (e) The initial cost of construction is more.
- (f) Speed of construction of flat roofs is less.

**Types of Flat Roofs:** All the types listed for upper floors can be used as flat roofs.

- 2. Pitched Roofs:** In the areas of heavy rain falls and snow fall sloping roof are used. The slope of roof shall be more than  $10^\circ$ . They may have slopes as much as  $45^\circ$  to  $60^\circ$  also. The sloped roofs are known as pitched roofs. The sloping roofs are preferred in large spanned structures like workshops, factory buildings and ware houses. In all these roofs covering sheets like A.C. sheet, G.I. sheets, tiles, slates etc. are supported on suitable structures. The pitched roofs are classified into

- (a) Single roofs
- (b) Double or purlin roofs
- (c) Trussed roofs.

- (a) **Single Roof:** If the span of roof is less than 5 m the following types of single roofs are used.

- (i) Lean to roofs
- (ii) Coupled roofs
- (iii) Coupled-close roof
- (iv) Collar beam roof

In all these roofs rafters placed at 600 mm to 800 mm spacing are main members taking load of the roof. Battens run over the rafters to support tiles. Figure 8.13 shows various types of single roofs.

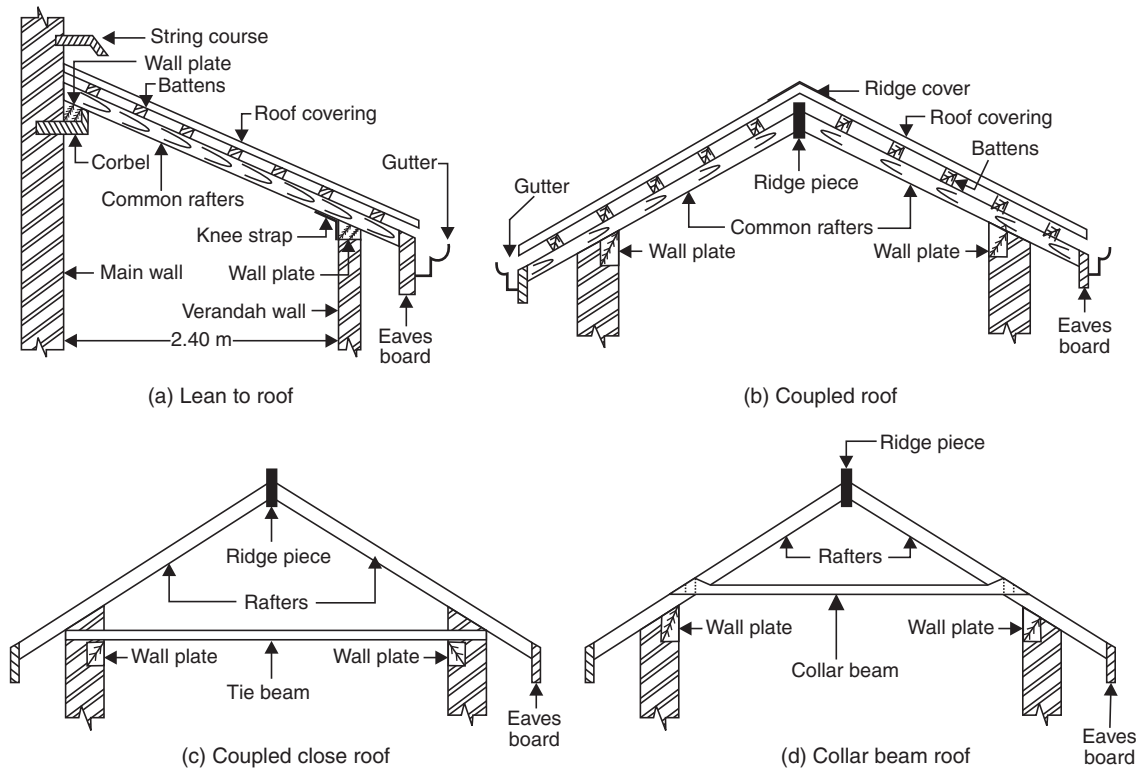


Fig. 8.13. Single roofs

(b) **Double or Purlin Roofs:** If span exceeds, the cost of rafters increase and single roof becomes uneconomical. For spans more than 5 m double purlin roofs are preferred. The intermediate support is given to rafters by purlins supported over collar beams. Figure 8.14 shows a typical double or purlin roof.

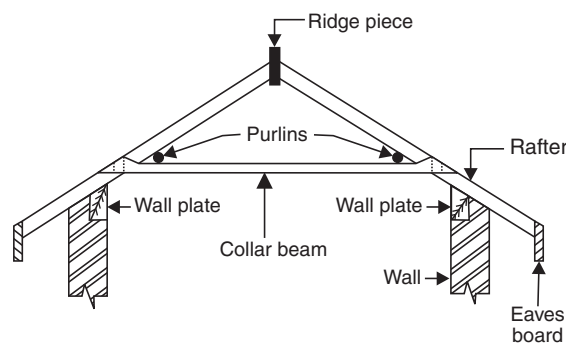


Fig. 8.14. Double or purlins roofs

(c) **Trussed Roof:** If span is more, a frame work of slender members are used to support sloping roofs. These frames are known as trusses. A number of trusses may be placed lengthwise to get wall free longer halls. Purlins are provided over the trusses which in turn support roof sheets. For spans up to 9 m wooden trusses may be used but for larger

spans steel trusses are a must. In case of wooden trusses suitable carpentry joints are made to connect various members at a joint. Bolts and straps are also used. In case of steel trusses joints are made using gusset plates and by providing bolts or rivets or welding. Depending upon the span, trusses of different shapes are used. End of trusses are supported on walls or on column. Figure 8.15 shows different shapes of trusses used. Figure 8.16 shows a typical wooden truss details and Fig. 8.17 shows the details of a typical steel truss.

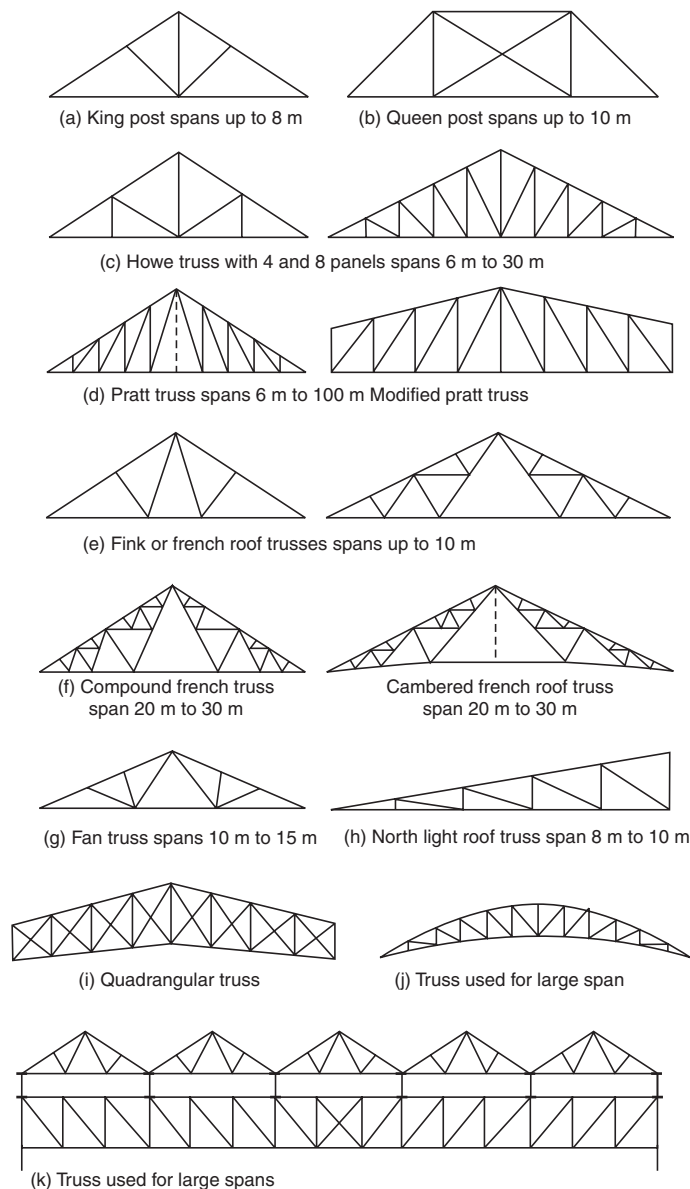


Fig. 8.15. Types of trusses

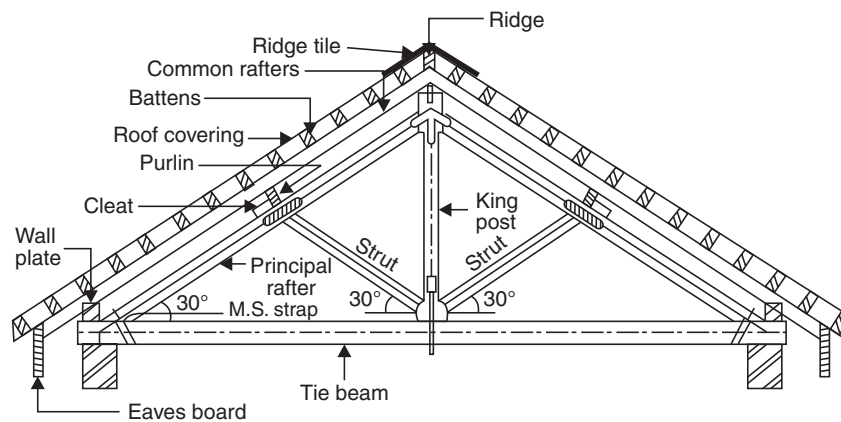


Fig. 8.16. A typical wooden truss (king post)

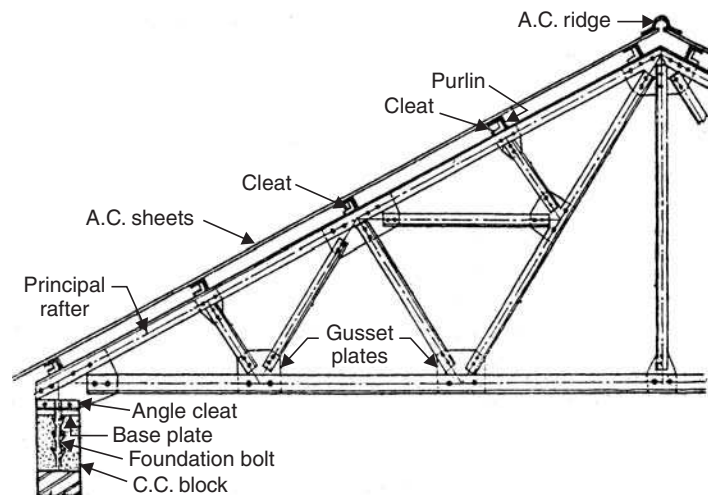


Fig. 8.17. Steel roof truss

**3. Shells and Folded Plate Roofs:** *Shell roof* may be defined as a curved surface, the thickness of which is small compared to the other dimensions. In these roofs lot of load is transferred by membrane compression instead of by bending as in the case of conventional slab and beam constructions. Caves are having natural shell roofs. An examination of places of worships built in India, Europe and Islamic nations show that shell structures were in usage for the last 800 to 1000 years. However the shells of middle ages were massive masonry structures but nowadays thin R.C.C. shell roofs are built to cover large column free areas. Figure 8.18 shows commonly used shell roofs.

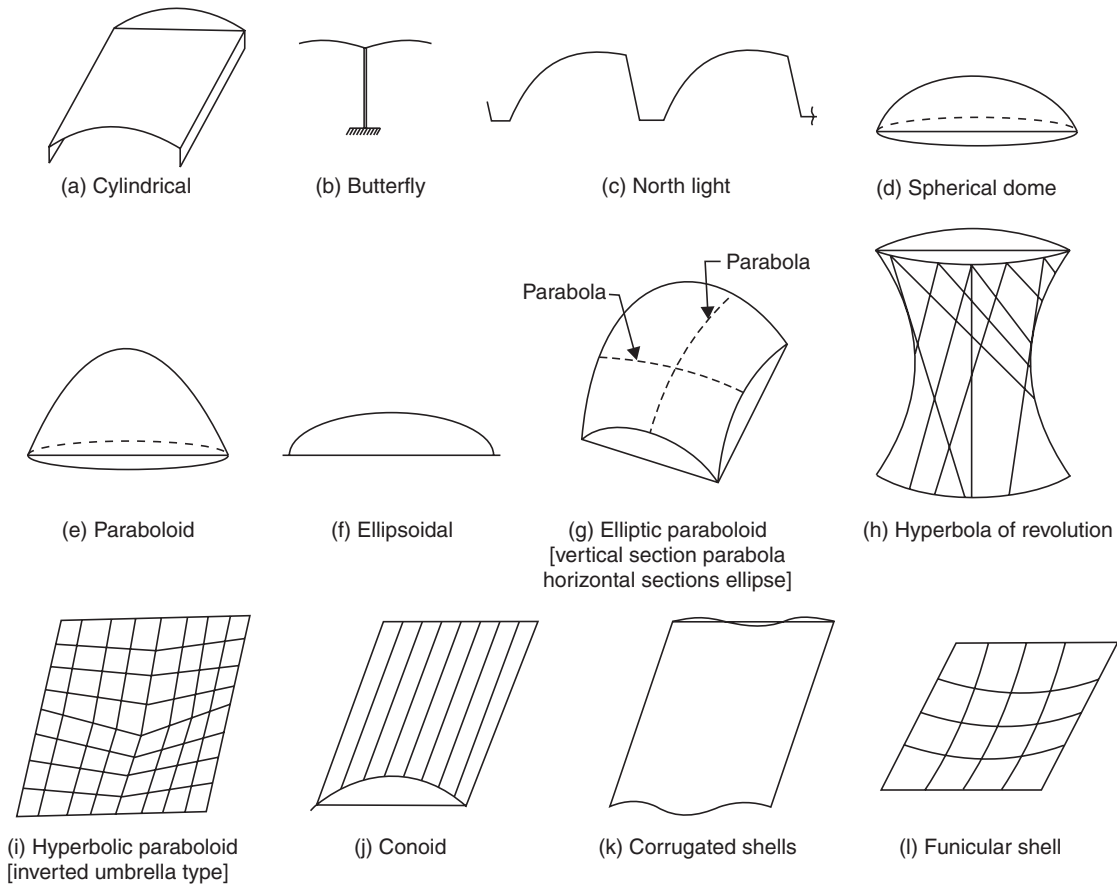


Fig. 8.18. Types of shell roof

### Advantages and Disadvantages of Shell Roofs

Advantages of shell roofs are:

- (a) Good from aesthetic point of view
- (b) Material consumption is quite less
- (c) Form work can be removed early
- (d) Large column free areas can be covered.

Disadvantages are:

- (a) Top surface is curved and hence advantage of terrace is lost.
- (b) Form work is costly.

Folded plate roofs may be looked as slab with a number of folds. These roofs are also known as hipped plates, prismatic shells and faltwerke. In these structures also bending is reduced and lot of load gets transferred as membrane compression. However folded plates are not so efficient as shells. Figure 8.19 shows typical folded plate roofs.

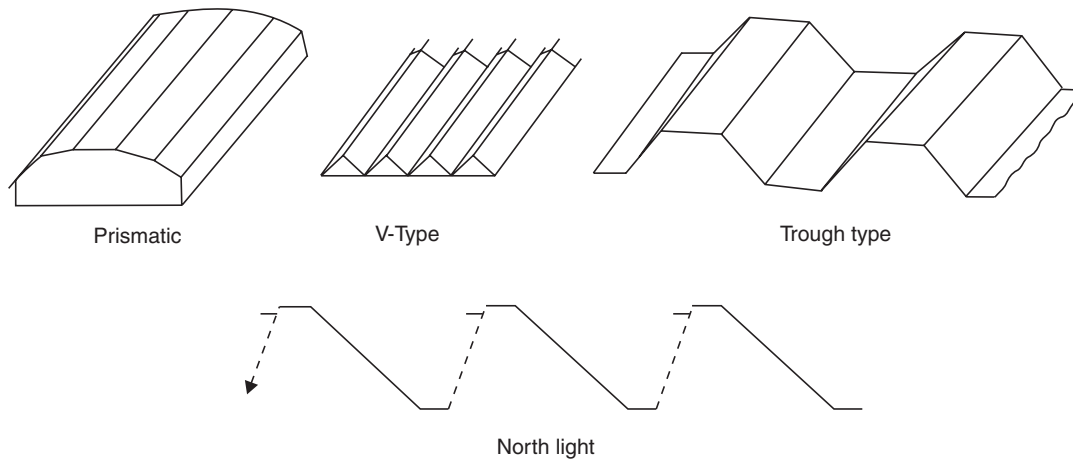


Fig. 8.19. Types of folded plate roofs

### Advantages and Disadvantages of Folded Plate Roofs Over Shell Roofs

Advantages are:

- (a) Form work required is relatively simpler.
- (b) Movable form work can be employed.
- (c) Design involves simpler calculations.

Disadvantages are:

- (a) Folded plate consume more material than shells.
- (b) Form work can be removed after 7 days while in case of shells it can be little earlier.

### Roof Coverings for Pitched Roofs

Various types of covering materials are available for pitched roofs and their selection depends upon the climatic conditions, fabrication facility, availability of materials and affordability of the owner. Commonly used pitched roof covering materials are:

- (a) Thatch
- (b) Shingle
- (c) Tiles
- (d) Slates
- (e) Asbestos cement (A.C.) sheets
- (f) Galvanised iron (G.I.) sheets

- (a) **Thatch Covering:** These coverings are provided for small spans, mainly for residential buildings in villages. Thatch is a roof covering of straw, reeds or similar materials. The thatch is well-soaked in water or fire resisting solution and packed bundles are laid with their butt ends pointing towards eaves. Thickness varies from 150 mm to 300 mm. They are tied with ropes or twines to supporting structures. The supporting structure consists of round bamboo rafters spaced at 200 mm to 300 mm over which split bamboos laid at right angles at close spacing. It is claimed that reed thatch can last 50 to 60 years while straw thatch may last for 20–25 years.

The advantage of thatch roof is they are cheap and do not need skilled workers to build them. The disadvantages are they are very poor fire resistant and harbour rats and other insects.

- (b) **Shingles:** Wood shingles are nothing but the split or sawn thin pieces of wood. Their size varies from 300 mm to 400 mm and length from 60 mm to 250 mm. Their thickness varies from 10 mm at one end to 3 mm at the other end. They are nailed to supporting structures. They are commonly used in hilly areas for low cost housing. They have very poor fire and termite resistance.
- (c) **Tiles:** Various clay tiles are manufactured in different localities. They serve as good covering materials. Tiles are supported over battens which are in turn supported by rafters/trusses etc. Allahabad tiles, Mangalore tiles are excellent inter-locking tiles. They give good appearance also.
- (d) **Slates:** A slate is a sedimentary rock. Its colour is gray. It can be easily split into thin sheets. Slates of size 450 mm to 600 mm wide, 300 mm long and 4 to 8 mm thick are used as covering materials of pitched roofs in the areas where slate quarries are nearby. A good slate is hard, tough, durable. They are having rough texture and they give ringing bell like sound when struck. They do not absorb water.
- (e) **A.C. Sheets:** Asbestos cement is a material which consists of 15 per cent of asbestos fibres evenly distributed and pressed with cement. They are manufactured in sufficiently large size. The width of a A.C. sheet varies from 1.0 to 1.2 m and length from 1.75 to 3.0 m. To get sufficient strength with thin sections they are manufactured with corrugation or with traffords [Fig. 8.20]. They are fixed to the steel purlins using J-bolts. The roofing is quite economical, waterproof. However not very good thermal resistant. They are commonly used as covering materials in ware houses, godowns or for larger halls. In auditorium etc., if these sheets are used, false ceilings are provided to get good thermal resistance.

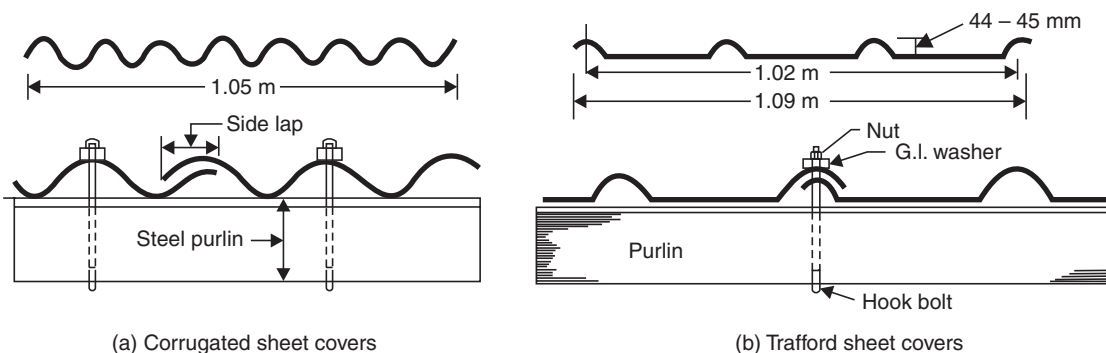


Fig. 8.20. A.C. sheet roofing

- (f) **G.I. Sheets:** Galvanised iron corrugated sheets are manufactured in the sizes 1.0 to 1.2 m wide and 1.65 m length. Galvanisation of iron makes them rust proof. They are fixed to steel purlins using J-bolts and washers. They are durable, fire proof, light in weight and need no maintenance. They are commonly used as covering materials for ware houses, godown, sheds etc. Table 8.6 gives comparison between GI and AC sheets for roof covering.

**Table 8.6.** Comparison between GI and AC sheets

<i>S. No.</i>	<i>GI Sheets</i>	<i>A.C. Sheets</i>
1.	Sheets are thin.	Not as thin as GI sheets.
2.	Light in weight.	Slightly heavier.
3.	Do not break while handling.	Chances of breaking are there during handling.
4.	Chances of corrosion can not be ruled out	No problem of corrosion.
5.	More noisy, if something falls over them.	Less noisy, if something falls over them.
6.	Less fire resistant.	More fire resistant.
7.	Less resistance to acids and fumes.	More resistant to acids and fumes.
8.	Cost is more.	Less costly.

## 8.9 DOORS AND WINDOWS

The function of a door is to give access to building and to different parts of the building and to deny the access whenever necessary. Number of doors should be minimum possible. The size of the door should be of such dimension as will facilitate the movement of the largest object likely to use the doors.

In case of the residential buildings, the size of the door should not be less than 0.9 m × 2.0 m. Larger doors may be provided at main entrance to the building to enhance the aesthetic view. Minimum sized doors are used for bath rooms and water closets. The size recommended is 0.75 m × 1.9 m. As a thumb rule height of door should be 1 m more than its width.

Windows are provided to give light and ventilation. They are located at a height of 0.75 m to 0.90 m from the floor level. In hot and humid regions, the window area should be 15 to 20 per cent of the floor area. It is preferable to have at least two openings in two different walls. Another thumb rule used to determine the size of the window opening is for every 30 m<sup>3</sup> inside volume there should be at least 1 m<sup>2</sup> window opening.

### Types of Doors

Various types of doors are in use which may be classified on the basis of arrangement of shutters, method of constructions, principles of working operations and materials used. Commonly used doors are briefly explained below:

**1. Battened and Lugged Doors:** Battens are 100 mm to 150 mm wide and 20 mm thick wooden boards. Their length is that of door opening. The battens are connected by horizontal planks, known as ledges of size 100 to 200 mm wide and 30 mm thick. Usually three ledges are used one at top, one at bottom and the third one at mid-height. This is the simplest form of door and the cheapest also. Battens are secured by tongued and grooved joint.



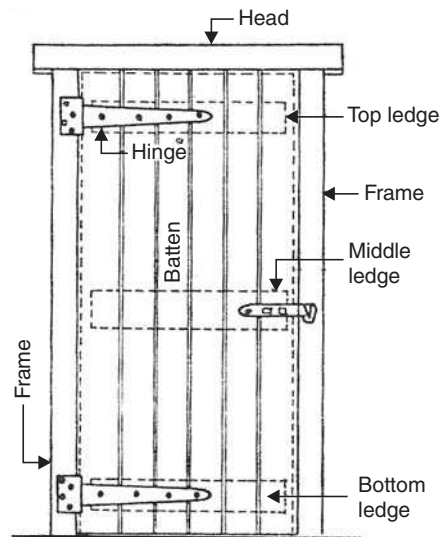


Fig. 8.21. Batted and ledged door

- 2. Batted, Ledged and Braced Doors:** If doors are wide apart from using battens and ledges diagonal members, known as braces, are provided to strengthen the door. Figure 8.22 shows a typical batted, ledged and braced door.

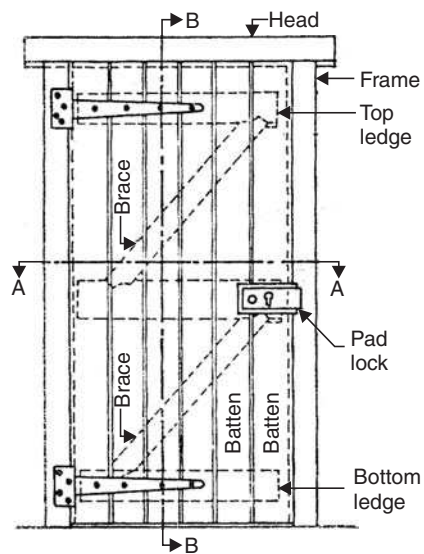


Fig. 8.22. Batted, ledged and braced door

Some times above two types of shutters are provided within wooden frame work and in those cases they may be called as *batted, ledges and framed doors*.

- 3. Framed and Panelled Doors:** This type of door consists of vertical members, called styles and horizontal members called rails. The styles and rails are suitably grooved to receive panels. The panels may be of wood, A.C. sheet, glasses etc. The panels may be flat or of raised type to get good appearance. These are very commonly used doors. They may be of single shutter or of double shutter. Figure 8.23 show few types of panelled doors. If glass panels are used they may be called as glazed doors.

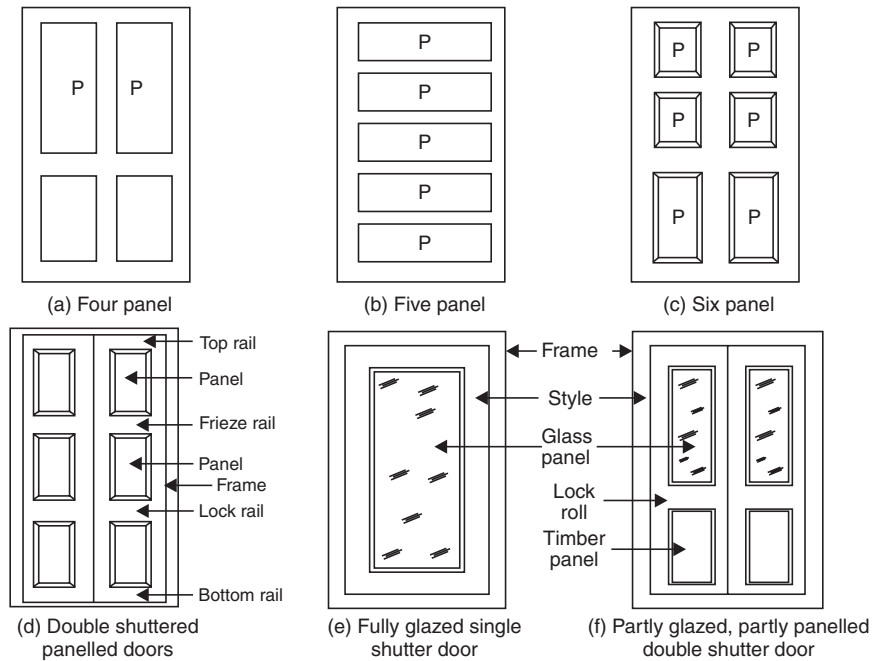


Fig. 8.23. Panelled and lazed doors

**4. Flush Doors:** The shutters of these doors are made of plywood or block boards. They are of uniform thickness. These shutters are available with different attractive vineer finishes. The time consumed in making such doors at site is quite less. These doors are suitable for interior portion of a building. Nowadays flush doors are commonly used in residential and office buildings. Figure 8.24 shows typical flush door.

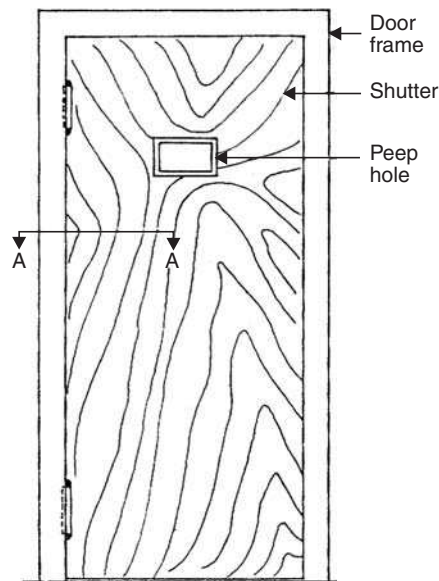


Fig. 8.24. Flush door

**5. Louvered Doors:** Whenever privacy as well as ventilation is required such doors can be used. Louvers are the glass, wooden or A.C. sheet strips fixed in the frame of shutter such that they prevent vision but permit free passage of air. The doors may be fully or partially louvered. Such doors are commonly used for public bathrooms and latrines. [Fig. 25]

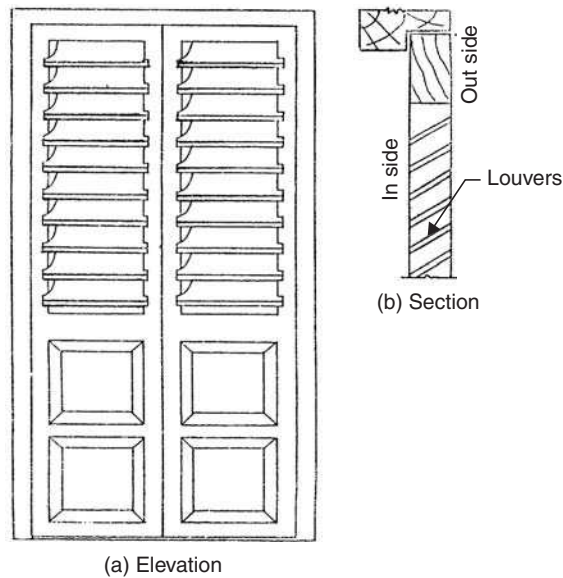


Fig. 8.25. Louvered door

**6. Revolving Doors:** It consists of a centrally placed pivot to which four radiating shutters are attached. The central pivot is supported on ball bearing at the bottom and has a bush bearing at the top. The shutters may be partly or fully made up of glass. A circular space of entrance is provided within which shutters rotate. As shutters rotate they give entrance on one side and exit on other side. These doors are preferred in public buildings like stores, banks, hotels, theatres where continuous use of doors is necessary. They are very much required in entrance to air conditioned public buildings. Figure 8.26 shows a typical revolving door.

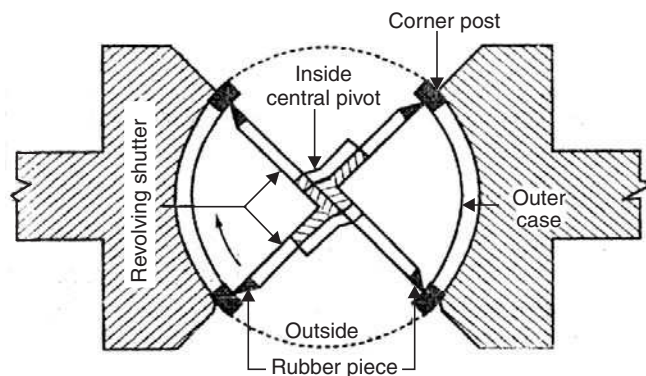


Fig. 8.26. Revolving door

**7. Swing Doors:** Swing door has its shutter attached to the frame by means of double action springs. Hence shutter can move both inward and outward. They may be single shuttered or double shuttered. Such doors are preferred in offices and banks. Since these doors can open on both sides it is desirable to provide glass panels or peep holes to enable user to see the persons from other side. [Fig. 8.27]

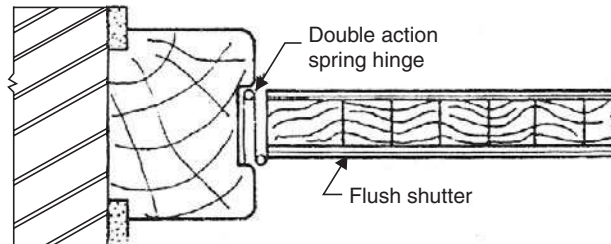


Fig. 8.27. Plan of swing door

**8. Sliding Doors:** In this type of doors, shutter slides on the sides. For this purpose runners and guide rails are provided. Sliding shutters may be one, two or even three. Such doors are used in banks, offices etc. The arrangement of such shutters in plan is shown in Fig. 8.28

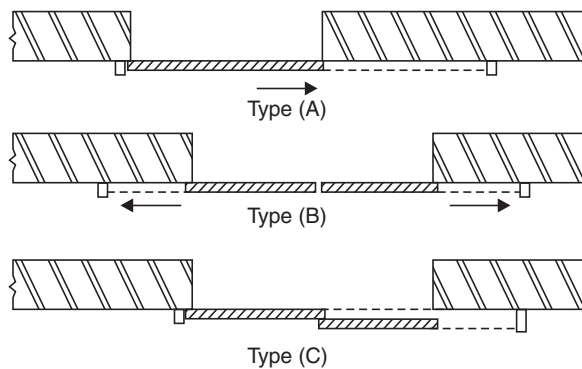


Fig. 8.28. Plan of sliding door

**9. Collapsible Doors:** Steel channels 16 to 20 mm wide are used as verticals. They are placed with 12 to 20 mm gap. Steel flats 16 mm to 20 mm wide and 5 mm thick are hinged to them

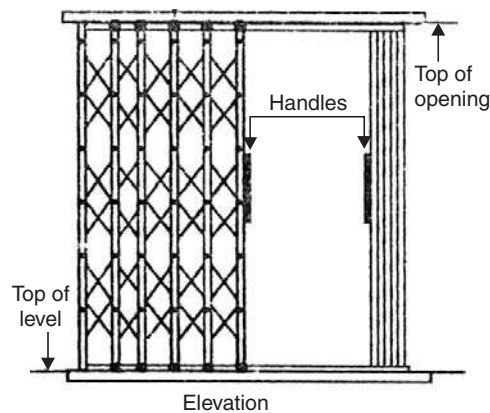


Fig. 8.29. Collapsible steel door

as shown in Fig. 8.29. The rollers are provided at their top as well as at bottom so that shutter can be pulled or pushed side ways with slight force. There may be single or double shutters. Usually these doors are used for additional safety. They are commonly used for front doors, bank locker rooms, school and college entrance doors.

**10. Rolling Shutters:** Figure 8.30 show a typical rolling shutter door. It consists of a frame, a drum and a shutter made of thin steel plates. The width of the door may vary from 2 to 3 m. The shutter moves on steel guides provided on sides and can easily roll up. For this counterbalancing is made with helical springs on the drum. The shutter can be easily pulled down. This type of doors are commonly used as additional doors to shops, offices, banks, factory, buildings from the point of safety.

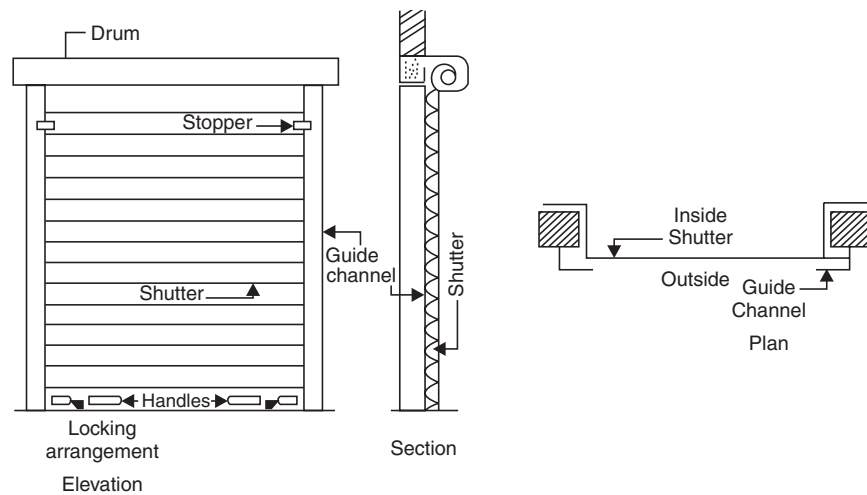


Fig. 8.30. Rolling shutter

Table 8.7 gives the differences between collapsible and revolving doors.

**Table 8.7.** Difference between collapsible and revolving doors

S. No.	Collapsible Doors	Revolving Doors
1.	These doors do not provide privacy inside a room.	Provide privacy inside a room.
2.	These doors operate side ways.	These doors revolve
3.	These doors provide exit and entry from same side.	These doors provide exit from one side and entry from the other side
4.	These doors are not suitable for entry to air conditioned halls.	These doors are suitable for A.C. halls.
5.	These doors do not close automatically when not in use.	These doors close openings automatically when not in use.

### Types of Windows

Various windows used may be classified on the basis of materials used, types of shutters, types of openings of shutters and the position of windows.

Timber, steel and aluminium are commonly used to make window frames. Timber may get termite attacks, steel may rust but aluminium do not have any such defects. However they are costly.

Shutters of windows may be panelled, glazed or louvered. Louvered windows are generally used for bathrooms and toilets where vision is not to be allowed but ventilation is required. Lower parts panelled and upper parts glazed windows are commonly used. Instead of panelled one may think of using translucent glasses. Figure 8.31 show a louvered windows.

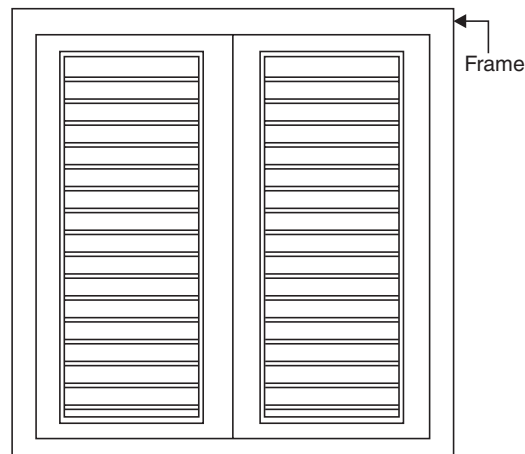


Fig. 8.31. Louvered window

Window shutters may be fixed, centrally pivoted, sliding type or double hung. Figure 8.32 shows a typical double hung window.

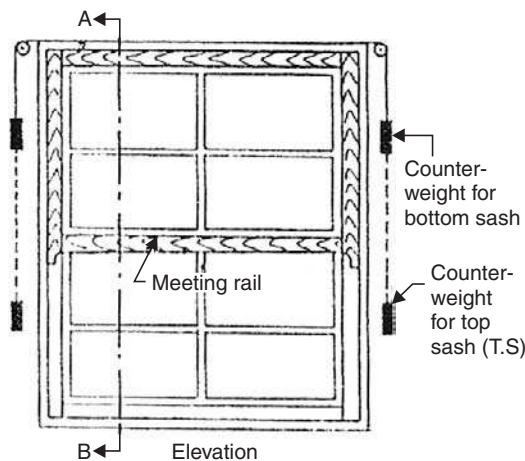


Fig. 8.32. Double hung window

Depending upon the position of windows, they may be classified as:

- (a) Casement windows
- (b) Bay windows
- (c) Corner windows

- (d) Clear storey windows
- (e) Gable windows
- (f) Sky light windows
- (g) Dormer windows
- (h) Ventilators

Casement windows are common type of windows, provided in the outer walls. They are provided over 50 to 75 mm sill concrete at a height of 750 to 900 mm from floor level.

Bay windows are provided on the projected portion of walls.

Corner windows are provided in the corner of a room. They need heavy lintels. Corner post of window should be strong enough to take load due to deflection of lintel and impact load from the shutters.

Clear storey windows are provided when the height of the room is much more than adjacent room/varandah. It is provided between the gap of low height room and the top of room with greater height.

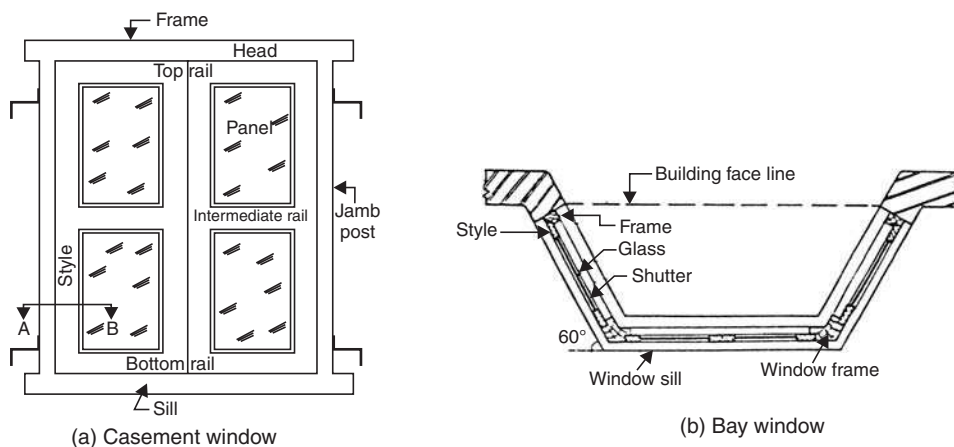
Gable windows are provided in the gable portion of the building. They are required in the stair cases or in the halls with gable walls.

Sky light windows are provided on a sloping roof. It projects above the top sloping surface. The common rafters are to be trimmed suitably.

Dormer windows are vertical windows on the sloping roof.

Ventilators are provided close to roof level or over the door frames. They help in pushing out exhaust air. They may be provided with two split and separated glasses or with hung shutters.

Various type of windows based on their positions are shown in Fig. 8.33



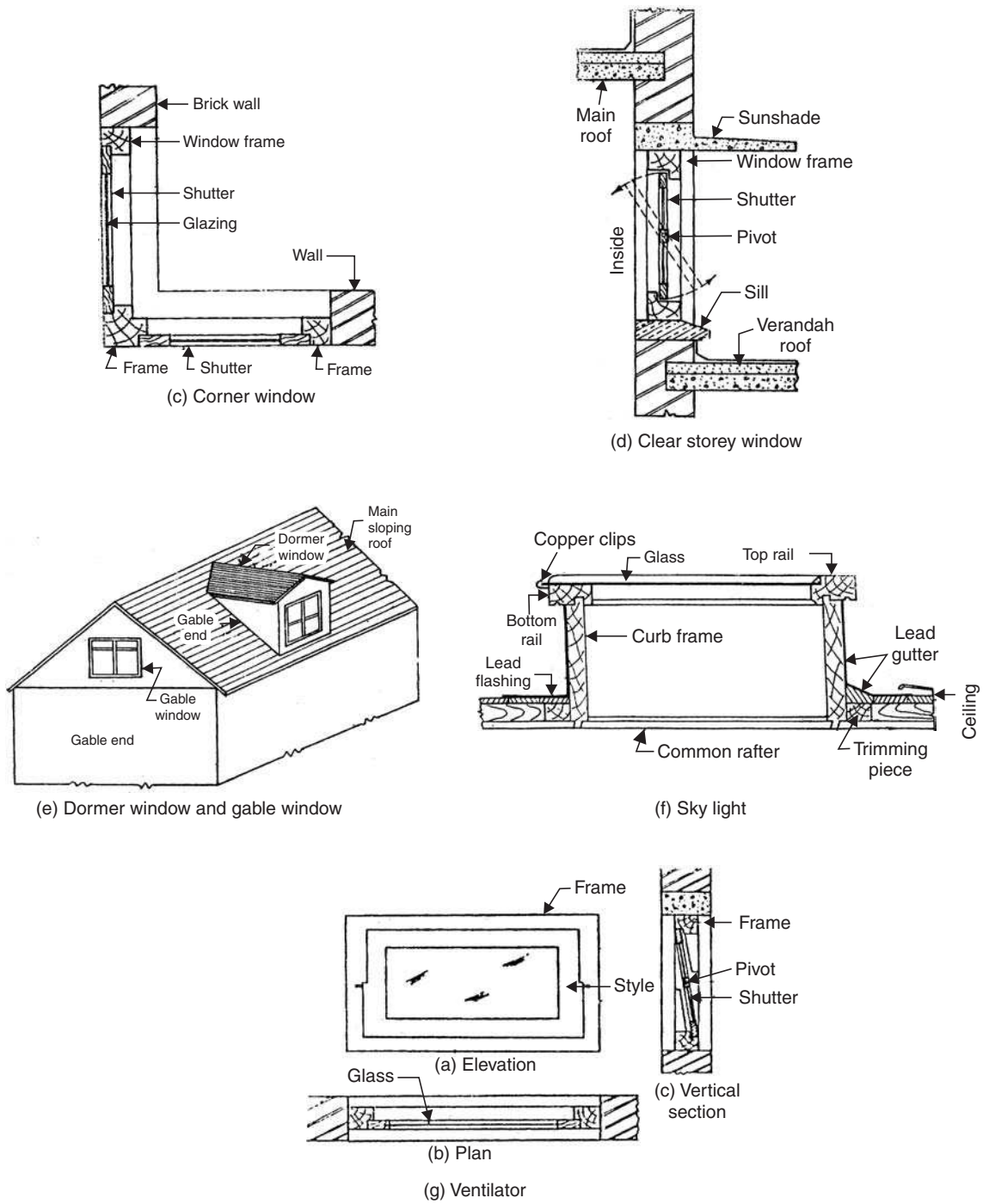


Fig. 8.33. Types of window on their position



## 8.10 LINTELS

Lintel is a horizontal flexural member which spans over the openings in the walls for doors, windows, ventilators, cupboards etc. The load of masonry above the opening is transferred to the wall by flexural action of the lintel so that frames of doors, windows etc are not unduly loaded. The end bearings for the lintel should be at least 200 mm. The width of lintels is same as that of wall.

Lintels of various materials are used. They are:

- (a) Wood
- (b) Stone
- (c) Brick
- (d) R.C.C. and
- (e) Steel.

(a) **Wood Lintel:** It may be a single piece or may be assembled by joining 2 to 3 pieces. Sometimes the wooden lintels are strengthened by steel plates at top and bottom. Such lintels are called as flitched beams.

(b) **Stone Lintels:** Wherever stones are available stone beams are used as lintels. As stone is weak in tension they can be used only for small spans. Their depth is kept about  $\frac{1}{10}$ th span.

Stones are cut to the width of wall and dressed before using as lintels.

(c) **Brick Lintels:** Well burnt, good quality lintels are laid on ends or edges to form lintels as shown in Fig. 8.34. It needs temporary form work at the time of construction. The lintel is to be cured for 7–14 days before form work is removed. Such lintels are useful to span small openings.

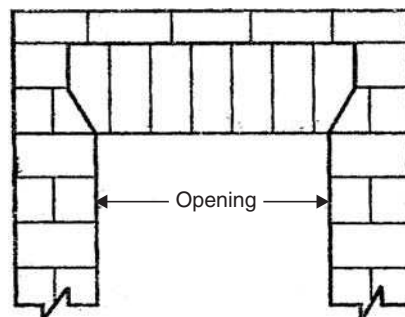


Fig. 8.34. Brick lintel

(d) **R.C.C. Lintels:** It is possible to provide R.C.C. lintels of any span required in the building. They can be isolated or continuous over the openings. They are provided with suitable reinforcement—main reinforcements being on lower side in the opening. Nowadays these lintels are used very commonly in buildings.

- (e) **Steel Lintels:** Steel angles or rolled steel I-sections are used as lintels. Tube separators may be provided to maintain the spacing between the sections. If the sections are opened to atmospheric action, regular painting is necessary. Many times they are encased in concrete to avoid maintenance problem. These lintels can be used for large openings.

## 8.11 STAIRS

Stairs give access from floor to floor. The space/room housing stairs is called staircase. Stairs consists of a number of steps arranged in a single flight or more number of flights.

The requirement of good stairs are

- (a) **Width:** 0.9 m in residential buildings and 1.5 m to 2.5 m in public buildings.
- (b) **Number of Steps in a Flight:** Maximum number of steps in a flight should be limited to 12 to 14, while minimum is 3.
- (c) **Rise:** Rise provided should be uniform. It is normally 150 mm to 175 mm in residential buildings while it is kept between 120 mm to 150 mm in public buildings. However in commercial buildings more rise is provided from the consideration of economic floor area.
- (d) **Tread:** Horizontal projection of a step in a stair case is called tread. It is also known as going. In residential buildings tread provided is 250 mm while in public buildings it is 270 mm to 300 mm.

The following empirical formula is used to decide rise and tread:

$$2R + T > 550 \text{ mm but } < 700 \text{ to } 600 \text{ mm}$$

where R is rise in mm and T is tread in mm.

- (e) **Head Room:** Head room available in the stair case should not be less than 2.1 m.
- (f) **Hand Rails:** Hand rails should be provided at a convenient height of a normal person which is from 850 mm to 900 mm.

### Types of Stairs

The stairs may be built with wood, concrete masonry or with cast iron. Wooden stairs are not safe, because of the danger of fire. However they are used in unimportant buildings to access to small areas in the upper floors. Cast iron or steel stairs in the spiral forms were used commonly to reduce stair case area. In many residential buildings masonry stairs are also used. Reinforced concrete stairs are very commonly used in all types of buildings.

Based on the shapes stairs may be classified as:

- (a) Straight stairs
- (b) Dog legged stairs
- (c) Well or open-newel stairs
- (d) Geometrical stairs
- (e) Spiral stairs

(f) Turning stairs.

(a) **Straight Stairs:** If the space available for stair case is narrow and long, straight stairs may be provided. Such stairs are commonly used to give access to porch or as emergency exits to cinema halls. In this type all steps are in one direction. They may be provided in single flight or in two flights with landing between the two flights [Fig. 8.35].

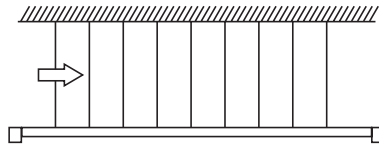


Fig. 8.35. Straight stairs

(b) **Dog Legged Stairs:** It consists of two straight flights with 180° turn between the two. They are very commonly used to give access from floor to floor. Figure 8.36 shows the arrangement of steps in such stairs.

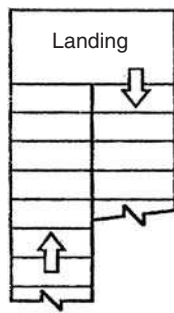


Fig. 8.36. Dog legged stair

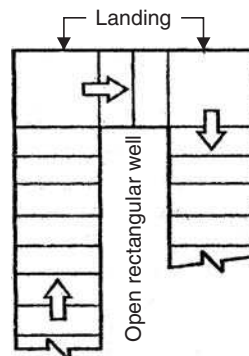


Fig. 8.37. Open well (newel) stair

(c) **Well or Open-newel Stairs:** It differs from dog legged stairs such that in this case there is 0.15 m to 1.0 m gap between the two adjacent flights. Figure 8.37 shows a typical open-newel stair.

(d) **Geometrical Stair:** This type of stair is similar to the open newel stair except that well formed between the two adjacent flights is curved. The hand rail provided is continuous. [Ref. Fig. 8.38]

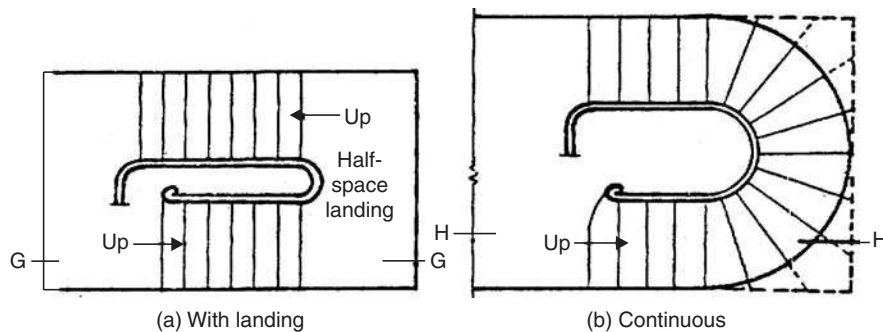


Fig. 8.38. Geometric stairs

- (e) **Spiral Stairs:** These stairs are commonly used as emergency exits. It consists of a central post supporting a series of steps arranged in the form of a spiral. At the end of steps continuous hand rail is provided. Such stairs are provided where space available for stairs is very much limited. Figure 8.39 shows a typical spiral stair. Cast iron, steel or R.C.C. is used for building these stairs.

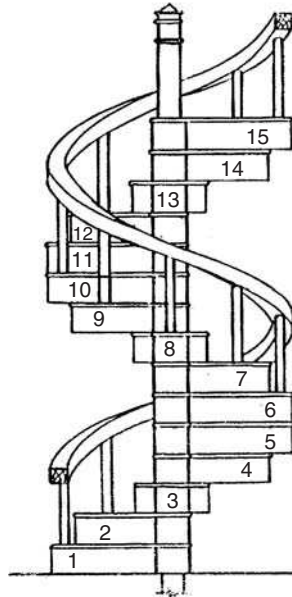


Fig. 8.39. Spiral stairs

- (f) **Turning Stairs:** Apart from dog legged and open newel type turns, stairs may turn in various forms. They depend upon the available space for stairs. Quarter turned, half turned with few steps in between and bifurcated stairs are some of such turned stairs. Figure 8.40 shows a bifurcated stair.

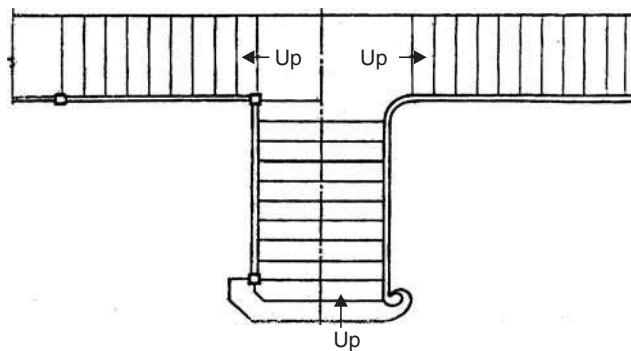


Fig. 8.40. Bifurcated stairs

**Salient Points to be Considered in Locating Stairs**

The following points should be considered in locating stairs in a building:

- (a) They should be located near the main entrance to the building.
- (b) There should be easy access from all the rooms without disturbing the privacy of the rooms.
- (c) There should be spacious approach.
- (d) Good light and ventilation should be available.

**QUESTIONS**

1. What is super structure ? Distinguish between load bearing and framed structure.
2. Distinguish between load bearing wall and partition wall.
3. Write short notes on
  - (i) partition wall
  - (ii) rubble and ashlar masonry.
4. State various points to be kept in mind in supervising
  - (i) stone masonry
  - (ii) brick masonry
5. Distinguish between
  - (i) Stretcher and header bond
  - (ii) English and Flemish bond
  - (iii) Double flemish and single flemish bond.
6. Explain different types of bonds used in brick masonry with sketches.
7. State advantages and disadvantages of brick masonry over stone masonry.
8. What is plaster ? State common proportions used in plaster. List the objective of plaster.
9. What are the requirements of good plaster ? State number of coats and their thicknesses used in different types of plasters.
10. Write short note on pointing.
11. Distinguish between plastering and pointing.
12. What are the different types of flooring ? Briefly explain any four of them.
13. Distinguish between terrazo flooring and mosaic flooring.
14. With sketches explain reinforced brick slab and hollow tiled flooring.
15. State advantages and disadvantages of flat roofs.
16. State different types of single roofs and give their sketches.
17. What is a truss ? What are the different materials used for making trusses ? Give sketches of any four types of trusses.
18. Write short notes on
  - (i) Shell roof
  - (ii) Folded plate roof.

19. Explain the advantages and disadvantages of
  - (i) Shell roofs over beam-slab construction
  - (ii) Folded plate roof over shell roof.
20. Write short notes on the following roof coverings
  - (i) thatch
  - (ii) shingle
  - (iii) tiles
  - (iv) slates.
21. Compare between A.C. and G.I. sheet coverings.
22. Write short notes on sizes of doors and windows.
23. Sketch the following types of doors
  - (i) Battened and ledged
  - (ii) Battened, ledged and braced
  - (iii) Louvered.
24. Write short notes on
  - (i) revolving doors
  - (ii) swing doors
  - (iii) sliding doors
25. Distinguish between
  - (i) Collapsible and rolling shutters
  - (ii) Collapsible and revolving door.
26. Explain any four types of windows classified on the basis of their position.
27. Sketch gable, dormer, skylight and clear storey windows.
28. What is lintel ? Where do you use lintel? Briefly explain different types of lintels used.
29. Explain the terms rise and tread of stairs. Give the desirable relationship between them.
30. Sketch dog legged, open newel and geometric stairs.
31. Write short notes on straight stairs and spiral stairs.
32. What are the salient points to be considered in locating stairs?

## Dampness and Its Prevention

Dampness in a building is the presence of moisture in various parts of building like floor, wall, roof etc. The continuous dampness of building give rise to unhygienic condition, hence care should be taken to prevent such situation. In this chapter causes and effects of dampness are presented. Ideal materials required for prevention of dampness are discussed and various methods of preventing dampness are presented.

### 9.1 CAUSES OF DAMPNESS

Dampness may be caused by:

- (a) Ground water
- (b) Rain water and
- (c) Leakages from pipes.
- (a) **Dampness due to Ground Water:** All buildings are founded on soils. Soil holds water for a long time. Sometimes water level may rise and come in contact with foundation. Due to capillary action moisture from ground rises into foundation, floor and even in wall.
- (b) **Rain Water:** May enter the building components due to various reasons.
  - (i) **From wall top:** If top of wall is not protected with impervious course like concrete, water can enter the wall and keep it damp for a long time.
  - (ii) **From face of external walls:** Splashing of outer wall by rain results into moisture entering the wall. Poor plaster coat is the main source of this type of dampness.
  - (iii) **Improper fixing of downtake pipes:** If downtake pipes from roof are not properly fixed, a thin layer of water stagnates near the mouth of downtake pipes. This results into entry of rain water into roof and wall.
  - (iv) **Improper slopes to roof:** In flat roofs, many times this is the cause for the dampness of roofs. If slope is not given properly, water ponds are formed on the flat roof, which results into entry of water into slab. Once water enters the slab it remains for long time creating dampness.

- (v) **Defective construction:** Imperfect wall joints, improper slopes to chejja, construction joints in roof etc. cause dampness in buildings.
- (c) **Leakage from Pipes:** From over head tanks, pipes are taken over roof and along the wall. From bathrooms, toilets and kitchen water is drained out with different types of pipes. The pipes are joined to get required length and turns. Many times water leaks through joints resulting into moisture in building components.

## 9.2 ILL-EFFECTS OF DAMPNESS

Ill-effects of dampness are as listed below:

1. Patches develop and destroy the appearance of the building.
2. Colour wash, white wash and paintings are damaged.
3. Plaster crumbles.
4. Bricks and stones disintegrate endangering the building.
5. Steel in the slabs and beam start rusting. It reduces the life of structure.
6. Electric short circuits may takes place.
7. Flooring may settle.
8. Floor covers are damaged.
9. Wooden components of buildings like door frames, cupboard warp.
10. Dry rotting of wood takes place.
11. Termite becomes active and attack wooden articles.
12. Mosquito breeding takes place.
13. Darkness along with warmth and darkness breed germs giving rise to many diseases.

## 9.3 REQUIREMENTS OF AN IDEAL MATERIAL FOR DAMP PROOFING

The requirements of an ideal materials for damp proofing are:

1. It should be impervious.
2. It should be flexible.
3. It should be easy to carry out leak proofing joints.
4. It should be stable.
5. It should be durable. It's life should be as much as the life of building itself.
6. It should resist the load safely.
7. It should not contain sulphates, chloride and nitrates.
8. It should be cheap.



## 9.4 MATERIALS FOR DAMP PROOFING

The materials used for damp proofing are:

1. **Bitumen:** In hot condition it is highly flexible and can be applied with brush to the bedding of concrete or mortar. Thickness of coat provided is about 3 mm.
2. **Mastic asphalt:** It is a semirigid material. It is obtained by heating asphalt with sand and mineral fillers. It is perfectly impervious. It should be laid very carefully.
3. **Bituminous or asphaltic felt:** It is a flexible material which is available in rolls. It is provided on roof slabs and parapet walls with an overlap of 100 mm on sides. The laps are sealed with bitumen. They do not withstand heavy movements.
4. **Bricks:** Good bricks with water absorption less than 5 per cent are sometimes used to make damp proof courses. The bricks are laid in two to four courses in cement mortar.
5. **Stones:** Stones like granite, trap and slates may be laid over wall to its full width as damp proof course.
6. **Mortar:** Cement mortar of proportion 1 : 3 with small quantity of lime and water proofing agents are used to make a water proofing course to foundations, ground floor slabs, top of parapet walls etc. It may be used for plastering external walls.
7. **Concrete:** To check the rise of water into walls a course of 75 mm to 100 mm cement concrete  $1 : 1\frac{1}{2} : 3$  or  $1 : 2 : 4$  is provided before starting constructing walls. These courses may be provided with hot bitumen paint as an additional precaution.
8. **Metal sheets:** Aluminium, copper or lead sheets are provided to seal the construction joints. Over these sheets bituminous seal is provided.
9. **Plastic sheets:** Plastic sheets are very good course for damp proofing. They are made up of black polythene of thickness 1 mm.

## 9.5 METHODS OF DAMP PROOFING

Various methods of damp proofing are as given below:

1. Providing D.P.C. course
  2. Providing cavity walls
  3. Surface treatment
  4. Integral treatment
  5. Guniting and
  6. Pressure grouting.
1. **Providing damp proof course:** It consists of providing a damp proof course between the source of dampness and building component. The DPC may be with any water repellent

material like bitumen, mastic asphalt, cement concrete, metal or plastic sheets. DPC should cover full width of wall. It should be laid on levelled surface of mortar. Joints should be minimum and should not be at critical points. When horizontal DPC on roof is continued on vertical face of parapet wall, the junction should be filled with about 75 mm fillet of cement concrete. Figure 9.1 shows details of providing water proof course at plinth level. Whereas Figure 9.2 shows the details of water proofing course for wall and floor. Figure 9.3 shows details of water proofing course for basement.

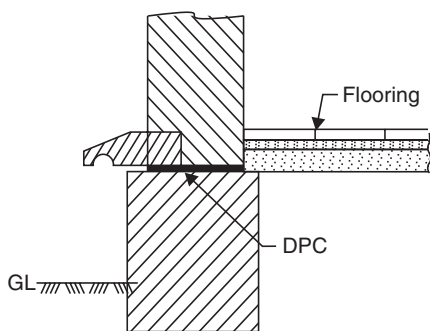


Fig. 9.1. DPC at plinth level

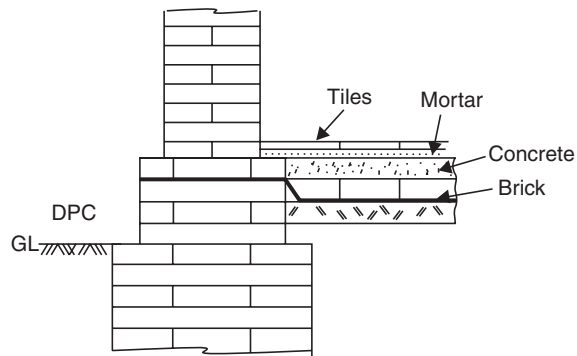


Fig. 9.2. DPC at floor level

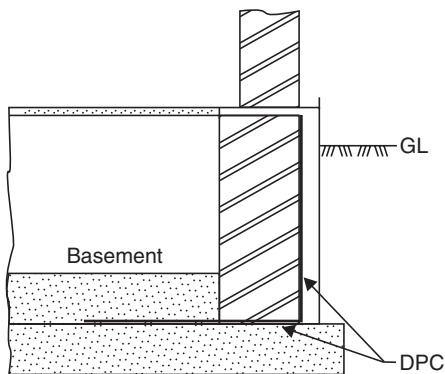


Fig. 9.3. DPC for basement

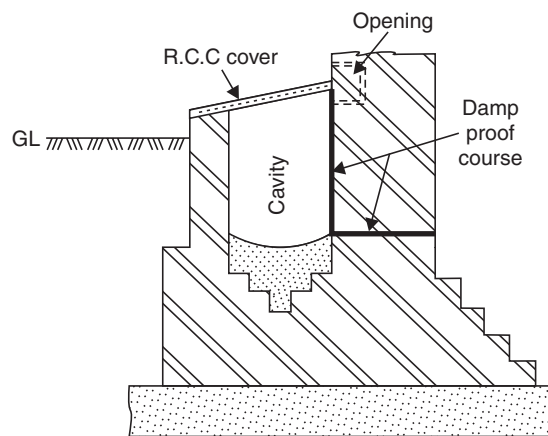


Fig. 9.4. Providing cavity wall

2. **Providing cavity wall:** Cavity wall may be constructed to protect foundation masonry and the wall as shown in Fig. 9.4. The cavity prevents moisture travelling from outer to inner wall.
3. **Surface treatment:** If moisture is only superficial and not under pressure this method is useful. It consists of application of layer of water repellent compounds on the surface. Some of the water proofing agents used for such treatment are silicates of sodium or potassium and sulphates of aluminium, zinc and magnesium.

4. **Integral treatment:** It consists in mixing commercially available compounds in water before concrete is wet mixed. These compounds are made from chalk, talc, flutter earth or chemical compounds like calcium chloride, aluminium sulphate, calcium chloride etc. Some compounds contain compounds like soap, petroleum oils, fatty acids etc.
5. **Guniting:** In this method a mixture of cement and water is forced by cement gun on the surface to be made water proof. Later 1 : 3 or 1 : 4 cement mortar is applied to the surface with pressure using compressed air. Thus an impervious layer of mortar is provided.
6. **Pressure grouting:** This is the method used to seal cracks in the concrete surfaces. In this method cement grout is forced under pressure.

## QUESTIONS

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1. What is dampness? Give various reasons for dampness.
2. List various ill effects of dampness.
3. What are the requirements of an ideal material for damp proofing?
4. Write short notes on the materials used for damp proof course.
5. With neat sketches explain various methods of damp proof works taken up in buildings.

## Cost Effective Construction Techniques In Mass Housing Schemes

Large per cent of the population of India is residing in temporary houses of mud, bamboo, thatched or erected from waste products in a very crude form. The temporary houses (Jhuggi) are not only unsafe but unhygienic to live in. Government of India and all state governments in India are aware of this massive problem and hence have established housing boards for development of housing sites and mass construction of houses. The national housing policy emphasises on the following:

1. Arrangement for selection and promotion of proven technology.
2. Promotion of manufacture of building materials and components through financial assistance, technical help, fiscal concessions.
3. Support extensive network of building centres.
4. Setting up of dedicated organization for technology, research, application and promotion concerning the following areas:
  - (a) Building materials and components.
  - (b) Selective approach to technology.
  - (c) Marketing through building centres.
  - (d) Franchising of the building centres.
  - (e) Development of appropriate standards.

As a result of this housing policy, a lot of fund flows to educational institutions and research centres for developing low cost housing technology, establishment of Nirmithi Kendras and good number of mass housing works coming under Ashraya Yojana.

### 10.1 MINIMUM STANDARDS

It is obvious that cost of construction is directly proportional to the area covered. In low cost housing economy in the construction is a vital factor, but one should not lose sight of the fact that any economies effected are not worth, if the minimum requirements of basic physical comfort in the dwellings are not met. In order to meet these twin requirements of economy and comfort, one has to depend to the maximum extent on the cost effective construction technology to provide minimum standard accommodation. On the recommendations of the planning commission, the Government of India has adopted the following minimum standards:

1. A living room	11.1 m <sup>2</sup>
2. A varandah and kitchen	6.5 m <sup>2</sup>
3. A bathroom	1.3 m <sup>2</sup>
4. A Lavatory	1.1 m <sup>2</sup>
	<u>20.0 m<sup>2</sup></u>

Figure 10.1 shows typical plans for low cost passing.

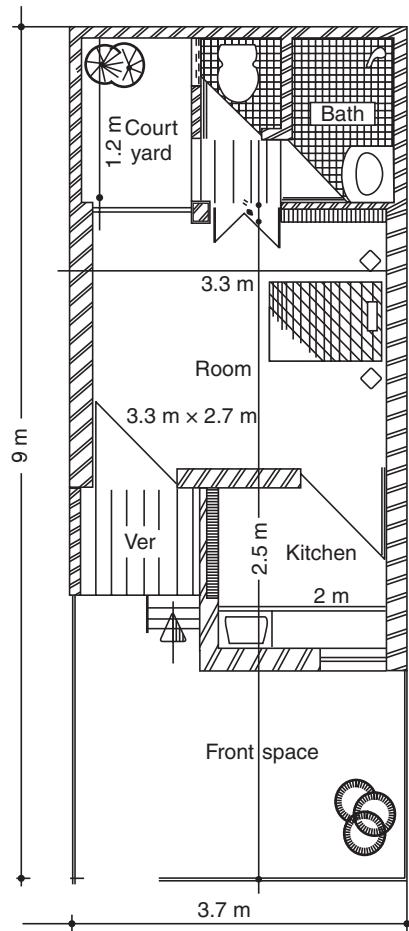


Fig. 10.1

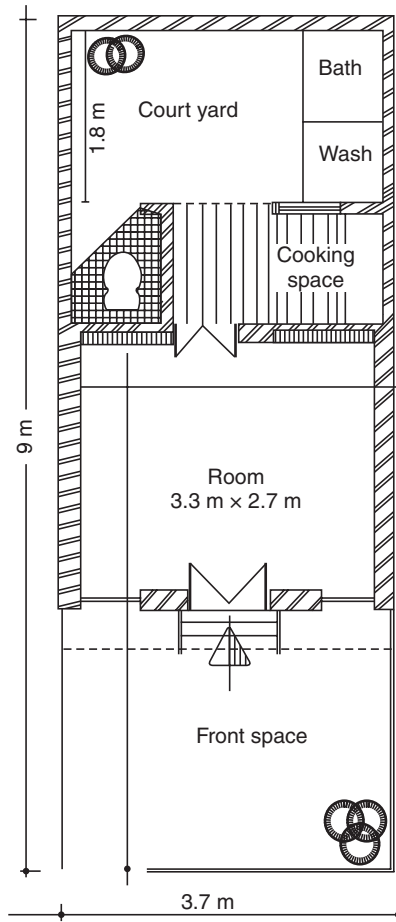


Fig. 10.2

## 10.2 APPROACH TO COST EFFECTIVE MASS HOUSING SCHEMES

The following steps are required to solve acute shortage of reasonable low cost houses:

1. **Development of Sites:** Government and government agencies should identify suitable sites for developing sites for low cost houses. The sites should be provided with water supply, sanitation, roads, street lighting and public transport facility. The area should be provided with shopping, education and health services to suit socio-economical, cultural and environmental conditions.

2. **Financial Assistance:** Poor people should be given financial assistance in the form of grant and cheap loan to build the low cost houses.
3. **Construct Model Low Cost Houses:** Few model low cost houses should be built to show the technology of building low cost houses.
4. **Self Help Schemes:** Low income people are capable of helping themselves in building shelter at acceptable cost. Self help housing programmes consists of motivating the beneficiaries, extending technical know how and skilled worker required for some works.
5. **Skeleton Housing:** Technical know how for building skeleton of housing should be made known to beneficiary. They should be allowed to make certain changes and improvements in final finishing to suit their financial position and taste.

### 10.3 COST EFFECTIVE CONSTRUCTION TECHNIQUES

Extensive research and development works have been taken place at various research centres to use local materials, waste materials and prefabricated structural components to reduce the cost of construction. Some of the improved cost effective technology are listed below:

1. **Foundation:** Under reamed piles for foundations have been developed for housing in black cotton soil area.
2. **Damp Proof Courses:** Use of polythene, bituminous materials and cement mortar with water proofing agents have been suggested for damp proof courses.
3. **Walls:** Fly ash bricks, precast hollow concrete blocks (without plaster), brick panels and precast wall panels may be used to get reasonably good comfort with little cost.
4. **Doors and Windows:** Precast R.C.C. frames can save 25 to 30 per cent cost when composed with wooden frames. Instead of wooden shutters particle board shutters may be used.
5. **Lintels and Chejja:** Locally available stones and slates can serve as lintels and chejja.
6. **Precast Structural Elements:** In mass constructions works precast members may be used for columns, beams, reapers and stair cases. One can think of using wall panels also.
7. **Roof Units:** A.C. sheets, cement bonded fibre sheets, paper corrugated sheets, lime and fly ash cellular slabs, solid planks, slates, ferrocement roof units etc. may be used for low cost housing roofs.
8. **Flooring:** Low cost housing flooring may be with soil cement base, thin clay tiles, bricks on edges or with flagstones.

If group housing is taken up automatically there is cost reduction, since mobilization of men, material cost is reduced and continuity of labour work is maintained.

### QUESTIONS

1. Write explanatory note on cost effective construction techniques.
2. What are the minimum standards recommended for low cost housing?
3. What is the suitable approach to cost effective mass housing works?

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# UNIT - III

## SURVEYING



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## Introduction to Surveying

**Surveying** is the art of making measurements of objects on, above or beneath the ground to show their relative positions on paper. The relative position required is either horizontal, or vertical, or both.

Less precisely the term **Surveying** is used to the measurement of objects in their horizontal positions. Measurements to determine their relative vertical positions is known as **levelling**.

### 11.1 OBJECT AND USES OF SURVEYING

As stated in the definition, object of surveying is to show relative positions of various objects of an area on paper and produce plan or map of that area. Various uses of surveying are listed below:

- (i) Plans prepared to record property lines of private, public and government lands help in avoiding unnecessary controversies.
- (ii) Maps prepared for marking boundaries of countries, states, districts etc., avoid disputes.
- (iii) Locality plans help in identifying location of houses and offices in the area.
- (iv) Road maps help travellers and tourist.
- (v) Topographic maps showing natural features like rivers, streams, hills, forests help in planning irrigation projects and flood control measures.
- (vi) For planning and estimating project works like roads, bridges, railways, airports, water supply and waste water disposal surveying is required.
- (vii) Marine and hydrographic survey helps in planning navigation routes and harbours.
- (viii) Military survey is required for strategic planning.
- (ix) Mine surveys are required for exploring mineral wealth.
- (x) Geological surveys are necessary for determining different strata in the earth crust so that proper location is found for reservoirs.
- (xi) Archeological surveys are useful for unearthing relics of antiquity.
- (xii) Astronomical survey helps in the study of movements of planets and for calculating local and standard times.

## 11.2 PRIMARY DIVISIONS IN SURVEYING

The earth is an oblate spheroid, length of equatorial axis being 12756.75 km and polar axis being 12713.80 km. Since the difference between these two axes and irregularities on the earth surface are very small (Note. Height of Mount Everest is 8.79 km) compared to these two axes, the earth may be treated as a sphere, Figure 11.1 shows a circular plane passing through a point  $A$  on the earth surface. The gravitational force is always directed towards the centre of the earth.

Hence, the plumb-line shown in Fig. 11.1 is a *vertical line*. Line perpendicular to vertical line (tangential to earth surface) is known as *horizontal line*. In surveying all measurement at any point are in the direction of these two lines.

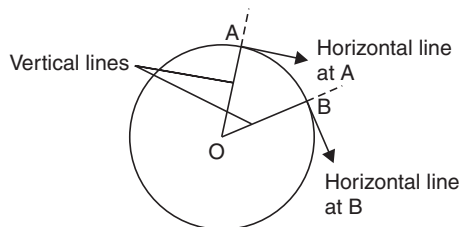


Fig. 11.1. Vertical and horizontal lines

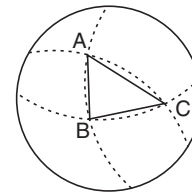


Fig. 11.2. Plane and spherical triangles

Obviously, the vertical and horizontal lines at another point  $B$  are not parallel to the respective lines at  $A$ . It should be noted that all lines lying on the earth's surface are curved lines and all triangles are spherical triangles as shown in Fig. 11.2. Hence, surveying involves spherical trigonometry.

If the area to be surveyed is small, the curvature of the earth may be neglected and all plumb lines treated as the same vertical. Hence, the lines normal to plumb line at any point in the area are treated as the same horizontal. All triangles in the area may be treated as plane triangles.

The survey in which earth curvature is neglected is called *Plane Surveying* and the survey in which earth's curvature is considered is known as *Geodetic Surveying*.

No definite value can be assigned to the area up to which a survey may be treated as plane, since the degree of accuracy required forms the controlling factor. However, the following points should be noted:

- (i) The length of an arc of 1.2 km on earth's mean surface is only 1 mm more than the straight line connecting those two points.
- (ii) The sum of the interior angles of a geometrical figure laid on the surface of the earth differs from that of the corresponding figure only to the extent of one second for about 200 square kilometres of area.

Hence, in most of engineering projects plane surveying is used. The geodetic surveying is used to determine the precise positions of control stations on the surface of the earth to which plane survey details are connected in works of larger magnitude like preparing maps of countries. Thus, in surveying there are two primary divisions *viz.* *Geodetic Surveying* and *Plane Surveying*.

### 11.3 FUNDAMENTAL PRINCIPLES OF SURVEYING

To get accurate results in surveying one should follow the following fundamental principles:

- (i) Work from whole to part
- (ii) Take extra care in fixing new control points.

#### 11.3.1 Work from Whole to Part

In surveying large areas, a system of control points are identified and they are located with high precision. Then secondary control points are located using lesser precise methods. The details of the localised areas are measured and plotted with respect to the secondary control points. This is called working from whole to part. This principle in surveying helps in localising the errors. If the surveying is carried out by adding localised areas errors accumulated and may become unacceptable when large area is covered.

#### 11.3.2 Extra Care in Fixing New Control Points

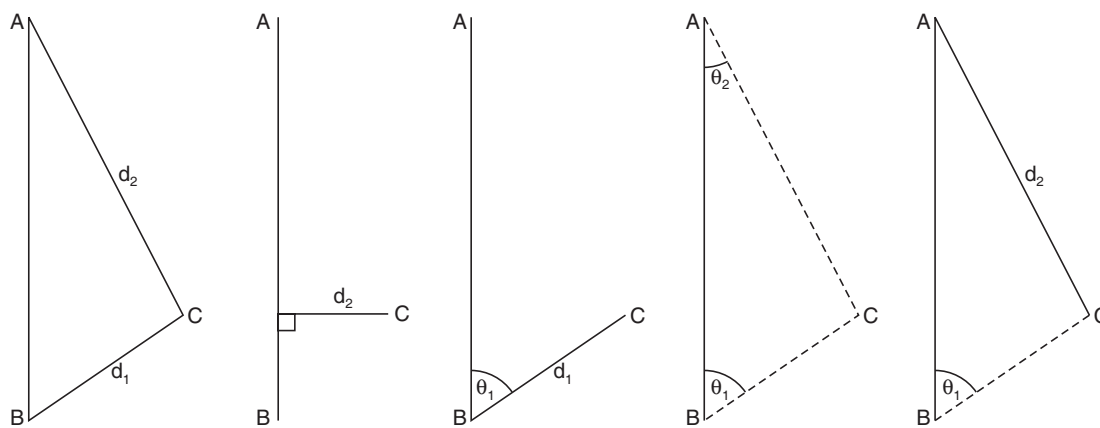


Fig. 11.3. Locating point C w.r.t. points A and B

Figure 11.3 shows the various methods of fixing point C with respect to already fixed points A and B by measuring sides, angles or setting perpendiculars. For fixing new control points (stations) with respect to already fixed points at least two independent process should be followed. If A and B are already located control points and with respect to them new control point C is to be located, apart from the minimum measurements required as shown in Fig. 11.3, one more measurement should be taken. Measuring the lengths of check lines and tie lines will also serve this purpose (Ref. Fig. 11.4).

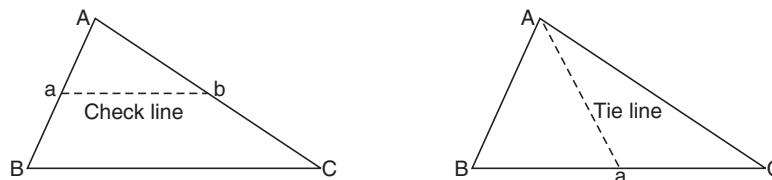


Fig. 11.4. Check line and tie line

## 11.4 CLASSIFICATION OF SURVEYING

Surveying may be classified on the following basis:

- (i) Nature of the survey field
- (ii) Object of survey
- (iii) Instruments used and
- (iv) The methods employed.

### 11.4.1 Classification Based on Nature of Survey Field

On this basis survey may be classified as land survey, marine or hydraulic survey and astronomical survey.

**Land Survey.** It involves measurement of various objects on land. This type of survey may be further classified as given below:

- (a) *Topographic Survey:* It is meant for plotting natural features like rivers, lakes, forests and hills as well as man made features like roads, railways, towns, villages and canals.
- (b) *Cadestral Survey:* It is for marking the boundaries of municipalities, villages, talukas, districts, states etc. The survey made to mark properties of individuals also come under this category.
- (c) *City Survey:* The survey made in connection with the construction of streets, water supply and sewage lines fall under this category.

**Marine or Hydrographic Survey.** Survey conducted to find depth of water at various points in bodies of water like sea, river and lakes fall under this category. Finding depth of water at specified points is known as sounding.

**Astronomical Survey.** Observations made to heavenly bodies like sun, stars etc., to locate absolute positions of points on the earth and for the purpose of calculating local time is known as astronomical survey.

### 11.4.2 Classification Based on Object of Survey

On the basis of object of survey the classification can be as engineering survey, military survey, mines survey, geological survey and archeological survey.

(a) *Engineering Survey:* The objective of this type of survey is to collect data for designing civil engineering projects like roads, railways, irrigation, water supply and sewage disposals. These surveys are further sub-divided into:

- Reconnaissance Survey* for determining feasibility and estimation of the scheme.
- Preliminary Survey* for collecting more information to estimate the cost of the project, and
- Location Survey* to set the work on the ground.
- (b) *Military Survey:* This survey is meant for working out plans of strategic importance.
- (c) *Mines Survey:* This is used for exploring mineral wealth.
- (d) *Geological Survey:* This survey is for finding different strata in the earth's crust.
- (e) *Archeological Survey:* This survey is for unearthing relics of antiquity.

### 11.4.3 Classification Based on Instruments Used

Based on the instruments used, surveying may be classified as:

- (i) Chain survey
- (ii) Compass survey
- (iii) Plane table survey
- (iv) Theodolite survey
- (v) Tacheometric survey
- (vi) Modern survey using electronic distance meters and total station
- (vii) Photographic and Aerial survey

The survey is taught to students mainly based on this classification.

### 11.4.4 Classification Based on Methods Employed

On this basis surveying is classified as triangulation and traversing.

(i) *Triangulation*: In this method control points are established through a network of triangles.

(ii) *Traversing*: In this scheme of establishing control points consists of a series of connected points established through linear and angular measurements. If the last line meets the starting point it is called as closed traverse. If it does not meet, it is known as open traverse [Ref. Fig. 11.5].

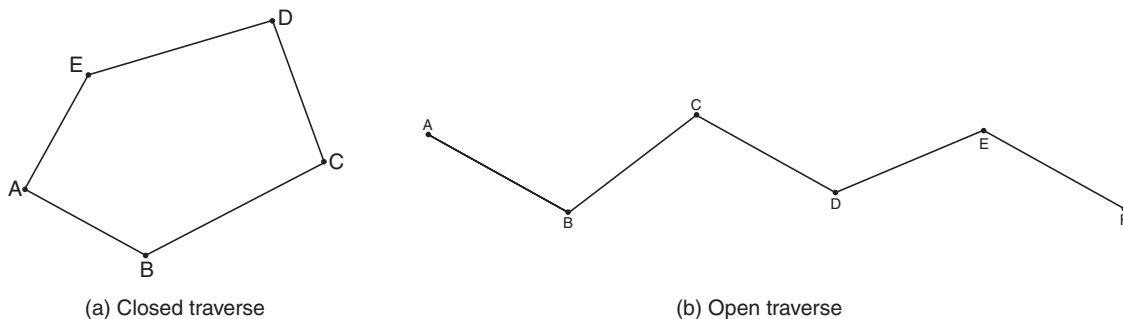


Fig. 11.5. Traversing

## 11.5 PLANS AND MAPS

As stated in the definition of surveying the objective of measurements is to show relative positions of various objects on paper. Such representations on paper is called plan or map. *A plan may be defined as the graphical representation of the features on, near or below the surface of the earth as projected on a horizontal plane to a suitable scale.*

However, since the surface of the earth is curved and that of the paper is plane, no part of the earth can be represented on such maps without distortion. If the area to be represented is small, the

distortion is less and large scale can be used. Such representations are called plans. If the area to be represented is large, small, scales are to be used and distortion is large. Representation of larger areas are called maps. Representation of a particular locality in a municipal area is a plan while representation of a state/country is a map. There is no exact demarcation between a plan and map.

## 11.6 SCALES

It is not possible and also not desirable to make maps to one to one scale. While making maps all distances are reduced by a fixed proportion. That fixed proportion is called scale of the map. Thus, if 1 mm on the paper represents 1 metre on the ground, then the scale of the map is 1 mm = 1 m or 1 mm = 1000 mm or 1 : 1000. To make scale independent of the units it is preferable to use representative factor which may be defined as the ratio of one unit on paper to the number of units it represent on the ground. Thus 1 mm = 1 m is equivalent to

$$RF = \frac{1}{1000}$$

Apart from writing scale on map, it is desirable to show it graphically on it. The reason is, over the time, the paper may shrink and the scaling down the distances from map may mislead. The graphical scale should be sufficiently long (180 mm to 270 mm) and the main scale divisions should represent one, ten or hundred units so that it can be easily read.

The scale of a map is considered as

(i) large if it is greater than 1 cm = 10 m *i.e.*,

$$RF > \frac{1}{1000}$$

(ii) intermediate if it is between

$$RF = \frac{1}{1000} \quad \text{and} \quad \frac{1}{10,000}$$

(iii) small if  $RF < \frac{1}{10,000}$

In general, scale selected should be as large as possible, since it is not possible for human eye to distinguish between two point if distance between them is less than 0.25 mm. The recommended scales for various types of surveys are as shown in Table 11.1.

**Table 11.1.** Recommended scales for various types of surveys

<i>Type of Survey</i>	<i>Scale</i>	<i>RF</i>
1. Building sites	1 cm = 10 m or less (1 : 1000 or less)	$\frac{1}{1000}$ or less
2. Town planning schemes and reservoirs	1 cm = 50 m to 100 m (1 : 5000 to 1 : 10000)	$\frac{1}{5000}$ to $\frac{1}{10000}$
3. Cadastral maps	1 cm = 5 m to 500 m (1 : 5000 to 1 : 50000)	$\frac{1}{500}$ to $\frac{1}{50000}$
4. Location surveys	1 cm = 50 m to 200 m (1 : 5000 to 1 : 20000)	$\frac{1}{5000}$ to $\frac{1}{20000}$
5. Topographic surveys	1 cm = 250 m to 2500 m (1 : 25000 to 1 : 250000)	$\frac{1}{25000}$ to $\frac{1}{250000}$
6. Geographic maps	1 cm = 5000 m to 160000 m (1 : 500000 to 1 : 16000000)	$\frac{1}{500000}$ to $\frac{1}{16000000}$
7. Route surveys	1 cm = 100 m (1 : 10000)	$\frac{1}{10000}$
8. Longitudinal sections		
(i) Horizontal scale	1 cm = 10 m to 200 m (1 : 1000 to 1 : 20000)	$\frac{1}{1000}$ to $\frac{1}{20000}$
(ii) Vertical scale	1 cm = 1 m to 2 m (1 : 100 to 1 : 200)	$\frac{1}{100}$ to $\frac{1}{200}$
9. Cross-sections (Both horizontal and vertical scales same)	1 cm = 1 m to 2 m (1 : 100 to 1 : 200)	$\frac{1}{100}$ to $\frac{1}{200}$

## 11.7 TYPES OF GRAPHICAL SCALES

The following two types of scales are used in surveying:

- (i) Plain Scale
- (ii) Diagonal Scale.

### 11.7.1 Plain Scale

On a plain scale it is possible to read two dimensions directly such as unit and tenths. This scale is not drawn like ordinary foot rule (30 cm scale). If a scale of 1 : 40 is to be drawn, the markings are not like 4 m, 8 m, 12 m etc. at every 1 cm distance. Construction of such a scale is illustrated with the example given below:



■ **Example 11.1:** Construct a plain scale of  $RF = \frac{1}{500}$  and indicate 66 m on it.

**Solution.** If the total length of the scale is selected as 20 cm, it represents a total length of  $500 \times 20 = 10000 \text{ cm} = 100 \text{ m}$ . Hence, draw a line of 20 cm and divide it into 10 equal parts.

Hence, each part correspond to 10 m on the ground. First part on extreme left is subdivided into 10 parts, each subdivision representing 1 m on the field. Then they are numbered as 1 to 10 from right to left as shown in Fig. 11.6. If a distance on the ground is between 60 and 70 m, it is picked up with a divider by placing one leg on 60 m marking and the other leg on subdivision in the first part. Thus field distance is easily converted to map distance.

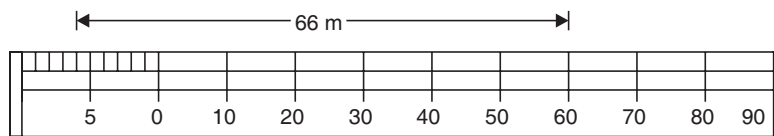


Fig. 11.6

IS 1491—1959 recommends requirements of metric plain scales designated as A, B, C, D, E and F as shown in Table 11.2. Such scales are commonly available in the market. They are made of either varnished cardboard or of plastic materials. Such scales are commonly used by surveyors and architects.

**Table 11.2.** Recommended plain scales

Designation	Scale	RF
A	Full size	1/1 (1:1)
	50 cm to a metre	1/2 (1:2)
B	40 cm to a metre	1/2.5 (1:2.5)
	20 cm to a metre	1/5 (1:5)
C	10 cm to a metre	1/10 (1:10)
	5 cm to a metre	1/20 (1:20)
D	2 cm to a metre	1/50 (1:50)
	1 cm to a metre	1/100 (1:100)
E	5 mm to a metre	1/200 (1:200)
	2 mm to a metre	1/500 (1:500)
F	1 mm to a metre	1/1000 (1:1000)
	0.5 mm to a metre	1/2000 (1:2000)

### 11.7.2 Diagonal Scale

In plain scale only unit and tenths can be shown whereas in diagonal scales it is possible to show units, tenths and hundredths. Units and tenths are shown in the same manner as in plain scale. To show hundredths, principle of similar triangle is used. If  $AB$  is a small length and its tenths are to be shown, it can be shown as explained with Fig. 11.7 below.

Draw the line  $AC$  of convenient length at right angles to plain scale  $AB$ . Divide it into 10 equal parts. Join  $BC$ . From each tenth point on line  $AC$  draw lines parallel to  $AB$  till they meet line  $BC$ . Then line 1-1 represent  $\frac{1}{10}$  th of  $AB$ , 6-6 represent  $\frac{6}{10}$  th of  $AB$  and so on. Figure 11.8 shows the construction of diagonal scale with  $RF = \frac{1}{500}$  and indicates 62.6 m.

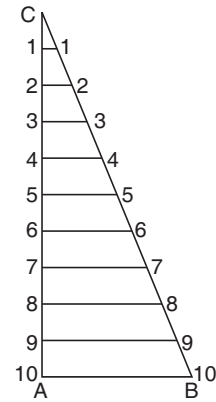


Fig. 11.7

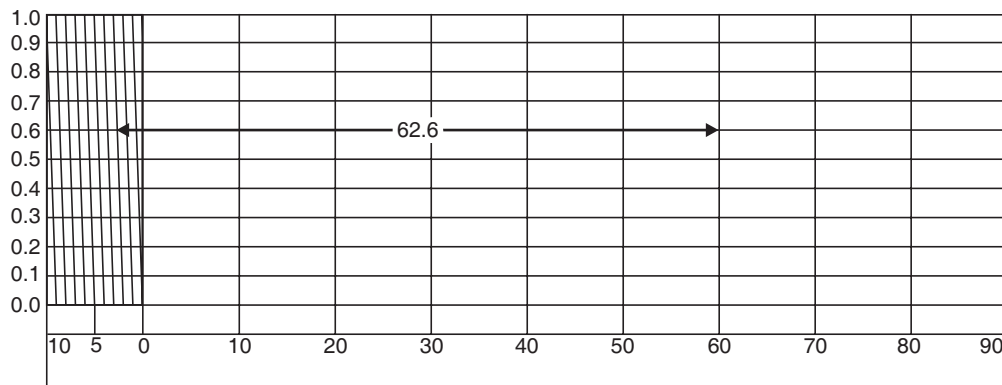


Fig. 11.8. Diagonal scale

IS 1562—1962 recommends diagonal scales  $A$ ,  $B$ ,  $C$ , and  $D$  as shown in Table 11.3.

Table 11.3. Indian standard diagonal scales (recommended)

Designation	RF	Total Graduated Length
A	$\frac{1}{1}$	150 cm
B	$\frac{1}{\frac{100000}{1}}$ $\frac{1}{50000}$ $\frac{1}{25000}$	100 cm
C	$\frac{1}{\frac{100000}{1}}$ $\frac{1}{50000}$ $\frac{1}{25000}$	50 cm

(Contd....)

D	$\frac{1}{100000}$ $\frac{1}{8000}$ $\frac{1}{4000}$	150 cm
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## 11.8 UNITS OF MEASUREMENTS

According to Standards of Weights and Measurements Act, India decided to give up FPS system used earlier and switched over to MKS in 1956. In 1960 System International (SI units) unit was approved by the conference of weights and measures. It is an international organisation of which most of the countries are the members. In this system also unit of linear measurement is metre. However, in this system use of centimeters and decimeters are discouraged. Of course major difference between MKS and SI is in the use of unit of force. In MKS unit of force is kg-wt (which is commonly called as kg only) while in SI it is newton.

The recommended multipliers in SI units are given below

$$\text{Giga unit} = 1 \times 10^9 \text{ units}$$

$$\text{Mega unit} = 1 \times 10^6 \text{ units}$$

$$\text{Kilo unit} = 1 \times 10^3 \text{ units}$$

$$\text{unit} = 1 \times 10^0 \text{ units}$$

$$\text{Milli unit} = 1 \times 10^{-3} \text{ unit}$$

$$\text{Micro unit} = 1 \times 10^{-6} \text{ unit}$$

Commonly used linear units in surveying are kilometre, metre and millimetres. However centimetre is not yet fully given up.

For measuring angles sexagesimal system is used. In this system:

$$1 \text{ circumference} = 360^\circ$$

$$1 \text{ degree} = 60' \text{ (minutes of arc)}$$

$$1 \text{ minute} = 60'' \text{ (seconds of arc)}$$

## QUESTIONS

1. What is surveying? State its objects and uses.
2. Distinguish between geodetic surveying and plain surveying.
3. Explain the terms topographical surveying and cadastral surveying.
4. What are the fundamental principles of surveying? Explain briefly.
5. Discuss the classifications of surveying based on
  - (i) instruments used
  - (ii) objective of survey and
  - (iii) methods employed.
6. Distinguish between plans and maps.
7. Explain with a neat sketch the construction of a diagonal scale to represent 1 cm = 5 m and show 53.6 m on it.

## Linear Measurements and Chain Surveying

All the distances required for making a plan are the horizontal distances. Hence in the field horizontal distances are measured or sufficient readings are taken to calculate horizontal distances. In this chapter the methods used for linear measurements are explained. Method of preparing a plan using only linear measurements is by conducting chain surveying. This method is also explained in this chapter and Indian Standard Conventions for showing objects on the map are presented at the end of the chapter.

### 12.1 METHODS OF LINEAR MEASUREMENTS

Various methods used for linear measurements may be grouped as:

- (i) Approximate
- (ii) Using chain or tape
- (iii) By optical means and
- (iv) Using electromagnetic distance measurement instruments.

#### 12.1.1 Approximates Methods of Linear Measurements

These methods are used in reconnaissance survey or to detect major mistakes committed while measuring with better methods. On smooth roads they can give results within 1 per cent error. These approximate measurements may be by:

- (i) pacing
  - (ii) using passometer
  - (iii) using pedometer
  - (iv) using odometer or by
  - (v) using speedometer.
- (i) **Pacing:** In this method surveyor walks along the line to be measured and counts the number of steps. Then the distance measured is equal to number of steps  $\times$  average length of a step. Average length of a step can be found by walking along a known length. A normal man takes a step of length 0.75 m to 0.8 m.

- (ii) **Using Passometer:** A passometer is a watch-like instrument which is carried vertically in the pocket of shirt or tied to a leg. It records number of steps taken. Thus the problem of counting number of steps is eliminated in this approximate method of linear measurement.
- (iii) **Using Pedometer:** This instrument is similar to passometer but it can record the distance instead of number of steps. In this, zero setting and setting of step length is made before walking.
- (iv) **Odometer:** This instrument is attached to the wheel of a cycle or other vehicle. It records the number of revolutions made by the wheel. Knowing the circumference of the wheel, the distance travelled may be found.
- (v) **Speedometer:** Odometer calibrated to give distance directly is called speedometer. This is to be used for particular vehicle only. All automobiles are provided with speedometers. By running the vehicle along the line to be measured distance can be found.

### 12.1.2 Measurement with Chains or Tapes

Measurement of distances using chain or tape is termed as chaining. This is the accurate and commonly employed method in surveying: These instruments can be classified as (i) chain (ii) steel band and (iii) tapes.

(i) **Chains:** The chains are composed of 100 pieces of 4 mm diameter galvanised mild steel wires bent into rings at the end and joined to each other by three circular or oval shaped rings. These rings give flexibility to the chain. The ends of chains are provided with swivel joints (Ref. Fig. 12.1(a)),

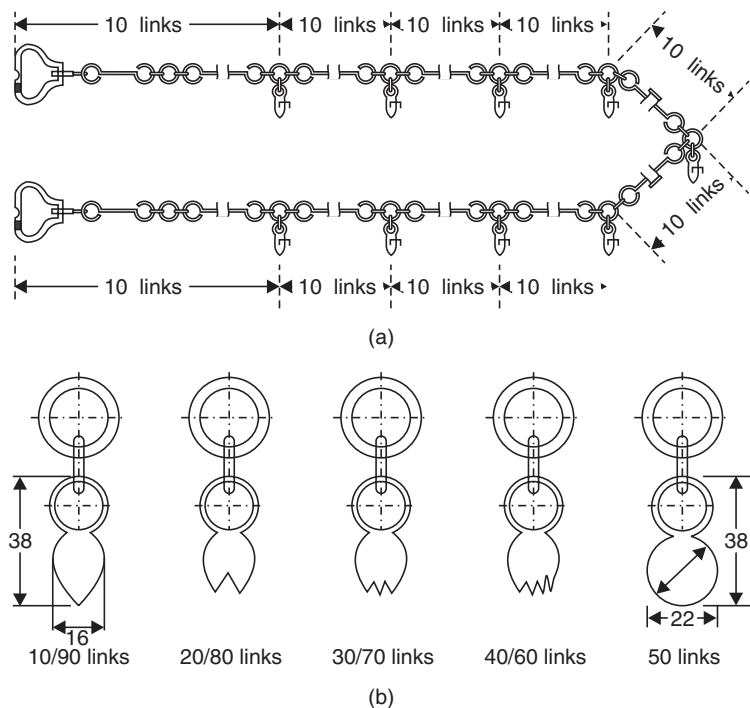


Fig. 12.1. Chain

so that the chain can be turned without twisting. To facilitate easy reading of the chain, brass tallies are provided. End of 10th link from each end is provided with a tally of one tooth, 20th link is provided with a tally of two teeth; 30th link with a tally of three teeth; 40th link with a tally of 4 teeth and the middle of chain is provided with a tally of circular shape [Ref. Fig. 12.1(b)].

It is to be noted that

- (i) length of a link is the distance between centres of two consecutive middle rings.
- (ii) the length of the chain is from outside of one handle to the outside of the other handle.

Commonly used metric chains are of 20 m length. They have 100 links with tallies at every 2 m. Each link is of 0.2 m length. Simple rings are provided at every one metre length except wherever tallies are provided. The total length of chain is marked on the brass handle.

However 30 m chains are also in use. Length of each link is 0.3 m. It is not so convenient as 20 m chain to read, since no rings can be provided at one metre distance and each link needs multiplication with 0.3 to arrive at metre units. However as a result the influence of using 100 ft chain in olden days, this type of chain are also in market.

**Steel Band:** It is also known as band chain. It consists of steel of 12 to 16 mm width and 0.3 to 0.6 mm thickness. The steel ribbon is wound around an open steel cross or in a metal reel (Ref. Plate 12.1). Metric steel bands are available in lengths of 20 m and 30 m. Any one of the following two methods of markings are used:

- (i) Providing brass studs at every 0.2 m and numbering at every metre. Last links from either end are subdivided in cm and mm.
- (ii) Etching graduations as meters, decimeters and centimeters on one side of the band and 0.2 m links on the other side.

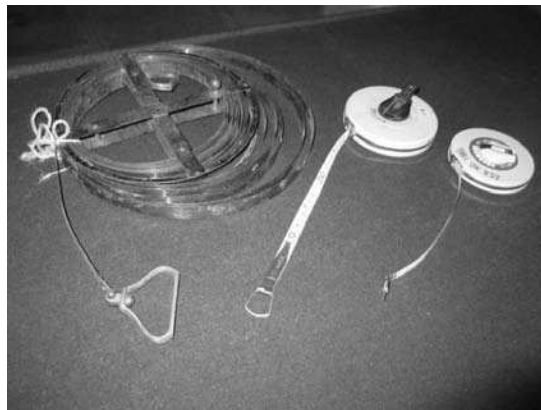


Plate 12.1

**Tapes:** Depending upon the materials used, they are classified as:

- (i) cloth or linen tape
- (ii) metallic tape
- (iii) steel tape and
- (iv) invar tape.



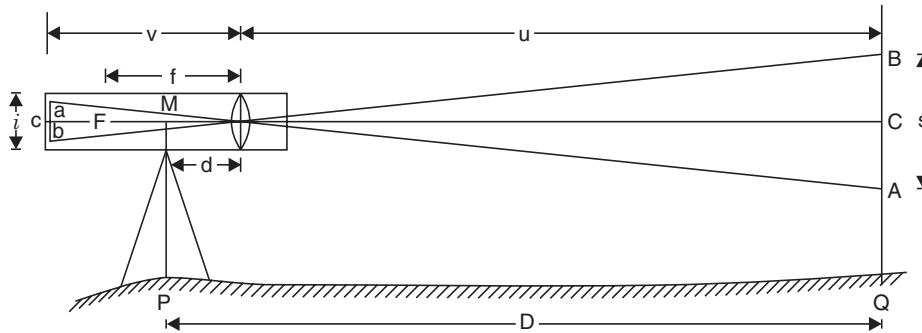


Fig. 12.4. Optical principle of linear measurement

$$\frac{v}{u} = \frac{i}{s} \quad \text{or} \quad u = v \frac{s}{i}$$

But from the law of optics,

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Multiplying throughout by  $uf$ , we get

$$u = f + \frac{u}{v} f = f + \frac{s}{i} f = f + \frac{f}{i} s$$

If the distance between objective lence at O and centre of telescope is 'd' then

$$\begin{aligned} D &= u + d \\ &= f + \frac{f}{i} s + d \\ &= ks + c \end{aligned} \quad \dots(12.1)$$

where

$$k = \frac{f}{i} \text{ and } c = f + d$$

$k$  and  $c$  are constants for a given instrument and hence can be found once for all. Thus distance between P and Q can be found by measuring vertical intercept 's'. Thus distance is measured by optical means easily. This is called Tacheometric measurement. But this measurement is not that accurate as obtained by measuring with chain or tape. For details of this method of survey, reader has to refer specialised books on 'surveying and levelling'.

### 12.1.4 Linear Measurement with Electromagnetic Distance Measurement Instruments

Nowadays for measuring distances electronic equipments called electromagnetic distance measurement (EDM) instruments have come in the market. They rely on the measurement of electromagnetic waves and measuring even fraction of wavelength by phase difference technique. They even display the distance measured. They are costly and delicate. Hence for ordinary surveying they are not used commonly. The details of such measurements are considered beyond the scope of this course.



## 12.2 INSTRUMENTS USED IN CHAINING

The following instruments are required for measurements with chain and tape:

- (i) Arrows
- (ii) Pegs
- (iii) Ranging rods and ranging poles
- (iv) Offset rods
- (v) Laths
- (vi) Whites
- (vii) Plumb bobs and
- (viii) Line ranger.

### 12.2.1 Arrows

When the length of the line to be measured is more than a chain length, there is need to mark the end of the chain length. Arrows are used for this purpose. A typical arrow is shown in Fig. 12.5. Arrows are made up of 4 mm diametered steel wire with one end sharpened and other end bent into a loop. Length of an arrow is approximately 400 mm.

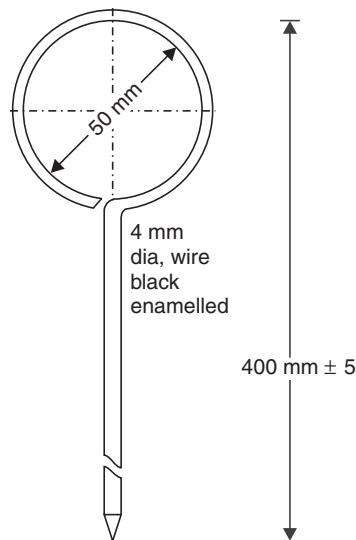


Fig. 12.5. Arrows

### 12.2.2 Pegs

Wooden pegs are used in measuring a length of a line to mark the end points of the line. The pegs are made of hard wood of 25 mm × 25 mm section, 150 mm long with one end tapered as shown in Fig. 12.6. When driven in ground to mark station points they project about 40 mm.

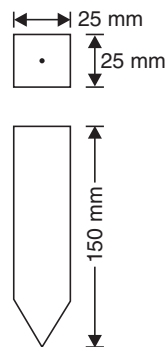


Fig. 12.6. Pegs

### 12.2.3 Ranging Rods and Ranging Poles

For ranging intermediate points along the line to be measured, ranging rods and ranging poles are used. Ranging rods are 2 to 3 m long and are made of hard wood. They are provided with iron shoe at one end as shown in Fig. 12.7.

They are usually circular in section with 30 mm diameter and are painted with 200 mm colour bands of red and white or with black and white. If distance is more than 200 m, for clear visibility they may be provided with multicoloured flags at their top. The ranging rods are occasionally used to measure short distances since they are painted with alternate colour of band 200 mm.

Ranging poles are similar to ranging rods except that they are longer. Their length varies from 4 m to 8 m and diameter from 60 mm to 100 mm. They are made of hard wood or steel. They are fixed in the ground by making 0.5 m holes and then packed to keep them vertical.

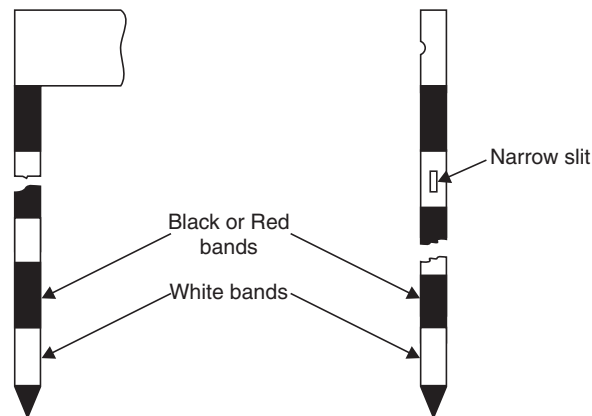


Fig. 12.7 Ranging rod

Fig. 12.8. Offset rod

### 12.2.4 Offset Rods

These rods are also similar to ranging rods and they are 3 m long. They are made up of hard wood and are provided with iron shoe at one end. A hook or a notch is provided at other end. At height of eye, two narrow slits at right angles to each other are also provided for using it for setting right angles. A typical offset rod is shown in Fig. 12.8.

### 12.2.5 Laths

Laths are 0.5 to 1.0 m long sticks of soft wood. They are sharpened at one end and are painted with white or light colours. They are used as intermediate points while ranging or while crossing depressions.

### 12.2.6 Whites

Whites are the pieces of sharpened thick sticks cut from the nearest place in the field. One end of the stick is sharpened and the other end is split. White papers are inserted in the split to improve the visibility. Whites are also used for the same purpose as laths.

### 12.2.7 Plumb Bob

A typical plumb bob is shown in Fig. 12.9. In measuring horizontal distances along sloping ground plumb bobs are used to transfer the position to ground. They are also used to check the verticality of ranging poles.

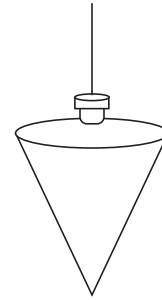


Fig. 12.9. Plumb bob

### 12.2.8 Line Ranger

It is an optical instrument used for locating a point on a line and hence useful for ranging. It consists of two isosceles prisms placed one over the other and fixed in an instrument with handle. The diagonals of the prisms are silvered so as to reflect the rays.

To locate point C on line AB (ref. Fig. 12.10) the surveyor holds the instrument in hand and stands near the approximate position of C. If he is not exactly on line AB, the ranging rods at A and B appear separated as shown in Fig. 12.10 (b). The surveyor moves to and fro at right angles to the line AB till the images of ranging rods at A and B appear in a single line as shown in Fig. 12.10 (c). It happens only when the optical square is exactly on line AB. Thus the desired point C is located on the line AB.

Its advantage is it needs only one person to range. The instrument should be occasionally tested by marking three points in a line and standing on middle point observing the coincidence of the ranging rods. If the images of the two ranging rods do not appear in the same line, one of the prism is adjusted by operating the screw provided for it.

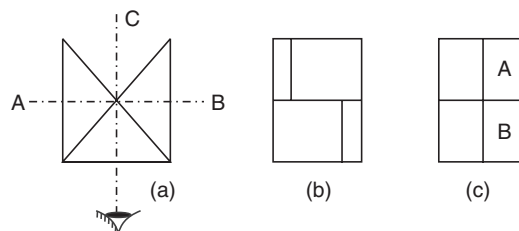


Fig. 12.10. Line ranger

## 12.3 CHAIN SURVEYING

Chain survey is suitable in the following cases:

- (i) Area to be surveyed is comparatively small

- (ii) Ground is fairly level
- (iii) Area is open and
- (iv) Details to be filled up are simple and less.

In chain surveying only linear measurements are made *i.e.* no angular measurements are made. Since triangle is the only figure that can be plotted with measurement of sides only, in chain surveying the area to be surveyed should be covered with a network of triangles. Figure 12.11 shows a typical scheme of covering an area with a network of triangles. No angle of the network triangles should be less than  $30^\circ$  to precisely get plotted position of a station with respect to already plotted positions of other station. As far as possible angles should be close to  $60^\circ$ . However, the arrangements of triangles to be adopted depends on the shape, topography, natural and artificial obstacles in the field.

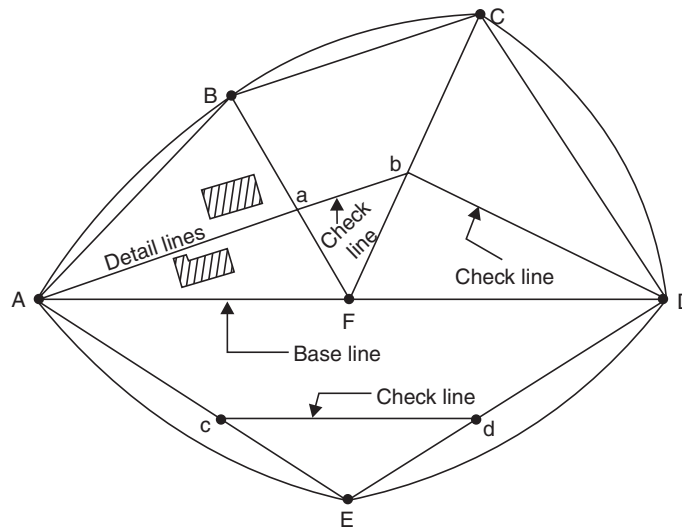


Fig. 12.11. Network of triangles

### 12.3.1 Technical Terms

Various technical terms used in connection with the network of the triangles in surveying are explained below:

*Station:* Station is a point of importance at the beginning or at the end of a survey line.

*Main station:* These are the stations at the beginning or at the end of lines forming main skeleton. They are denoted as A, B, C etc.

*Subsidiary or tie stations:* These are the stations selected on main lines to run auxiliary/secondary lines for the purpose of locating interior details. These stations are denoted as a, b, c, ..., etc., or as 1, 2, 3, ... etc.

*Base line:* It is the most important line and is the longest. Usually it is the line plotted first and then frame work of triangles are built on it.

*Detail lines:* If the important objects are far away from the main lines, the offsets are too long, resulting into inaccuracies and taking more time for the measurements. In such cases the secondary lines are run by selecting secondary stations on main lines. Such lines are called detail lines.

*Check lines:* These are the lines connecting main station and a substation on opposite side or the lines connecting to substations on the sides of main lines. The purpose of measuring such lines is to check the accuracy with which main stations are located.

### 12.3.2 Selection of Stations

The following points should be considered in selecting station points:

- (i) It should be visible from at least two or more stations.
- (ii) As far as possible main lines should run on level ground.
- (iii) All triangles should be well conditioned (No angle less than  $30^\circ$ ).
- (iv) Main network should have as few lines as possible.
- (v) Each main triangle should have at least one check line.
- (vi) Obstacles to ranging and chaining should be avoided.
- (vii) Sides of the larger triangles should pass as close to boundary lines as possible.
- (viii) Trespassing and frequent crossing of the roads should be avoided.

### 12.3.3 Offsets

Lateral measurements to chain lines for locating ground features are known as offsets. For this purpose perpendicular or oblique offsets may be taken (Ref. Fig. 12.12). If the object to be located (say road) is curved more number of offsets should be taken. For measuring offsets tapes are commonly used.

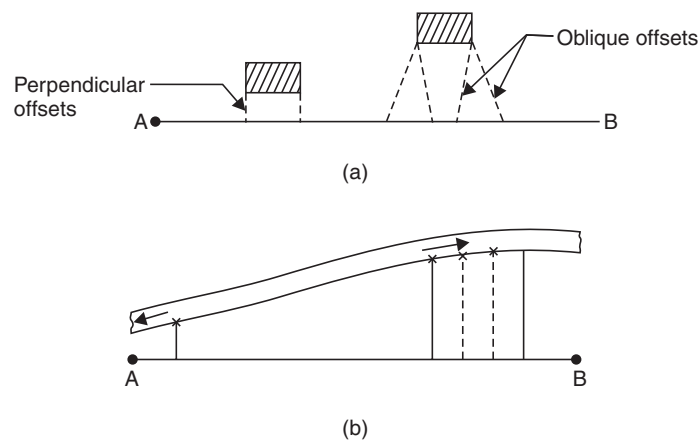
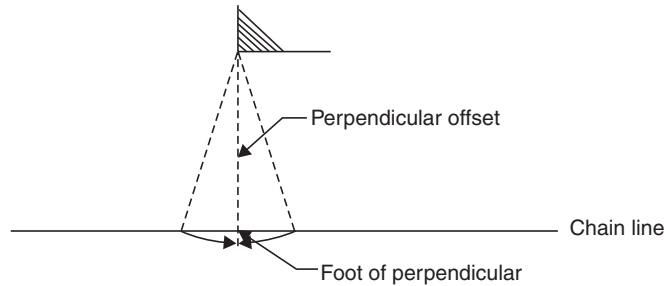


Fig. 12.12. Offsets

For setting perpendicular offsets any one of the following methods are used:

- (i) Swinging
- (ii) Using cross staffs
- (iii) Using optical or prism square.

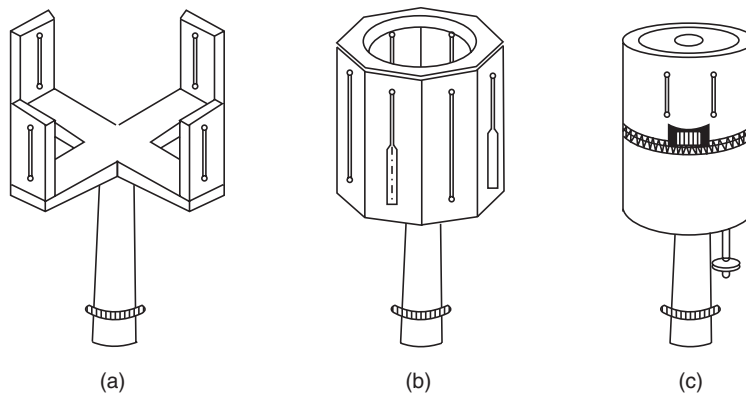
**Perpendicular Offset by Swinging**



**Fig. 12.13**

Chain is stretched along the survey line. An assistant holds the end of tape on the object. Surveyor swings the tape on chain line and selects the point on chain where offset distance is the least (Fig. 12.13) and notes chain reading as well as offset reading in a field book on a neat sketch of the object.

**Perpendicular Offsets Using Cross Staffs**



**Fig. 12.14. Cross staff**

Figure 12.14 shows three different types of cross staffs used for setting perpendicular offsets. All cross staffs are having two perpendicular lines of sights. The cross staffs are mounted on stand. First line of sight is set along the chain line and without disturbing setting right angle line of sight is checked to locate the object. With open cross staff (Fig. 12.14 (a)) it is possible to set perpendicular only, while with french cross staff (Fig. 12.14 (b)), even 45° angle can be set. Adjustable cross staff can be used to set any angle also, since there are graduations and upper drum can be rotated over lower drum.

**Perpendicular Offsets Using Optical Square and Prism Square**

These instruments are based on the optical principle that if two mirrors are at angle ‘θ’ to each other, they reflect a ray at angle ‘2θ’. Figure 12.15 shows a typical optical square.

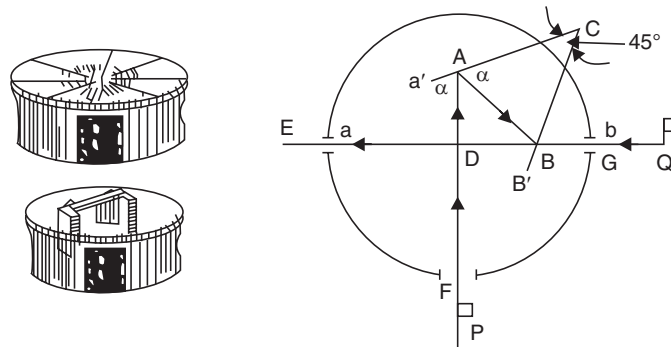


Fig. 12.15. Optical square

Optical square consists of a metal box about 50 mm in diameter and 125 mm deep. In the rim of the box there are three openings:

- (i) a pin hole at E
- (ii) a small rectangular slot at G, and
- (iii) a large rectangular slot at F.

A and B are the two mirrors placed at 45° to each other. Hence the image of an object at F which falls on A gets reflected and emerge at E which is at right angles to the line FA. The mirror A which is opposite to the opening at F is fully silvered. It is fitted to a frame which is attached to the bottom plate. If necessary this mirror can be adjusted by inserting a key on the top of the cover. The mirror B which is in the line with EG is silvered in the top half and plain in the bottom half. It is firmly attached to the bottom plate of the box.

The ranging rod at Q is directly sighted by eye at E in the bottom half of the B which is a plain glass. At the same time in the top half of B, the reflected ray of the object at P is sighted. When the image of P is in the same vertical line as the object at Q, then the lines PA is at right angles to the line EB.

This instrument can be used for finding foot of the perpendicular or to set a right angle.

In prism square, instead of two mirrors at 45° to each other a prism which has two faces at 45° to each other is used [Fig. 12.16.]. Its advantage is it will not go out of adjustment even after long usage.

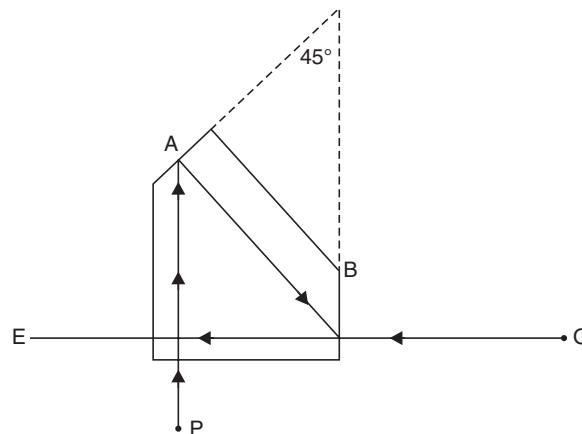


Fig. 12.16. Prism square

**12.3.4 Field Book**

All observations and measurements taken during chain surveying are to be recorded in a standard field book. It is a oblong book of size 200 mm × 120 mm, which can be carried in the pocket.

There are two forms of the book (i) single line and (ii) double line. The pages of a single book are having a red line along the length of the paper in the middle of the width. It indicates the chain line. All chainages are written across it. The space on either side of the line is used for sketching the object and for noting offset distances. In double line book there are two blue lines with a space of 15 to 20 mm in the middle of each book. The space between the two lines is utilised for noting the chainages. Figure 12.17 shows typical pages of a field books.

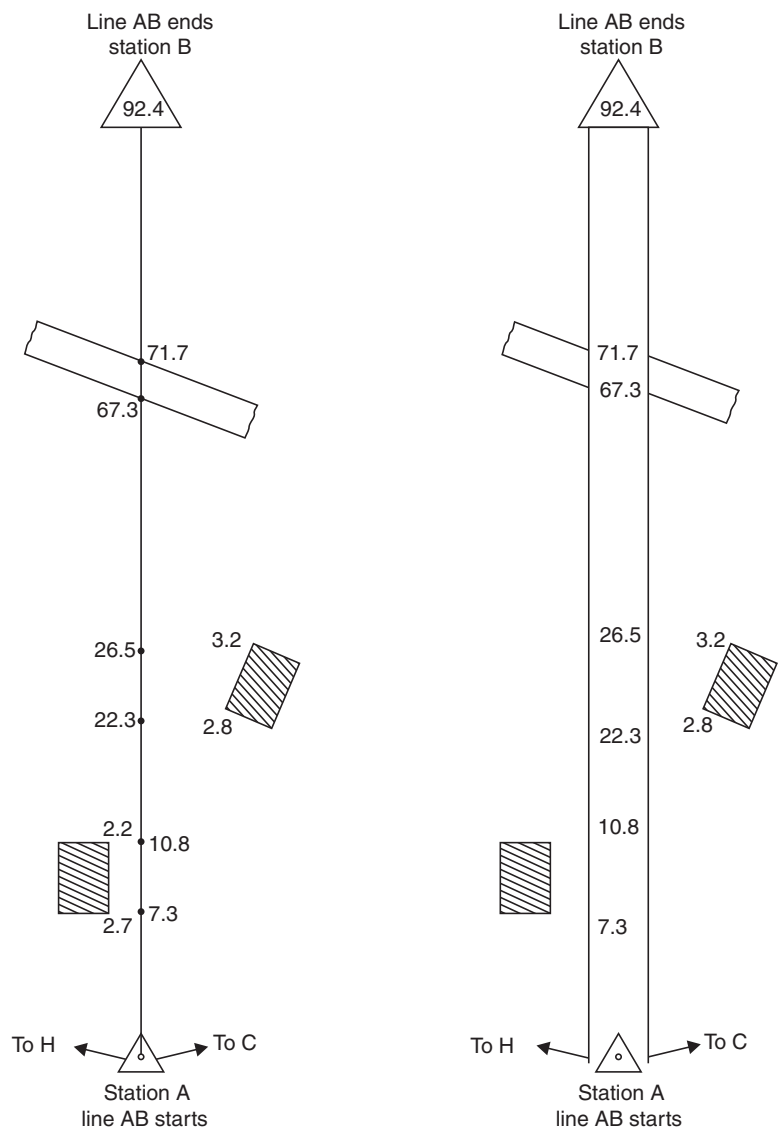


Fig. 12.17



### 12.3.5 Field Work

As soon as the survey party arrives in the field the following details are entered in the field book:

- (i) Title of the survey work
- (ii) The date of survey
- (iii) The names of the members of the party.

The field work may be divided into the following:

- (i) Reconnaissance survey.
- (ii) Marking stations, drawing reference sketches.
- (iii) Line by line surveying.

Reconnaissance survey consists in going round the field and identifying suitable stations for the network of triangles. Neat sketch of network is drawn and designated. The typical key plan drawn is similar to one shown in Fig. 12.11.

All main stations should be marked on the ground. Some of the methods used for marking are:

- (a) Fixing ranging poles
- (b) Driving pegs
- (c) Marking a cross if ground is hard
- (d) Digging and fixing a stone.

Then reference sketches are drawn in the field book so as to identify stations when the development works are taken up. For this measurements with respect to three permanent points are noted. The permanent points may be

- (a) Corner of a building
- (b) Posts of gates
- (c) Corners of compound walls
- (d) Electric poles
- (e) A tree.

After that, line by line surveying is conducted to locate various objects with respect to chain lines.

### 12.3.6 Office Work

It consists in preparing the plan of the area to a suitable scale making use of measurements and sketches noted in the field book.

## 12.4 RANGING

When a survey line is longer than a chain length, it is necessary to align intermediate points on chain line so that the measurements are along the line. The process of locating intermediate points on survey line is known as ranging. There are two methods of ranging viz., direct ranging and reciprocal ranging.

### 12.4.1 Direct Ranging

If the first and last points are intervisible this method is possible. Figure 12.18 shows the intervisible stations A and B in which an intermediate point C is to be located. Point C is selected at a distance slightly less than a chain length. At points A and B ranging rods are fixed. The assistant holds another ranging rod near C. Surveyor positions himself approximately 2 m behind station A and looking along line AB directs the assistant to move at right angles to the line AB till he aligns the ranging rod along AB. Then surveyor instructs the assistant to mark that point and stretch the chain along AC.

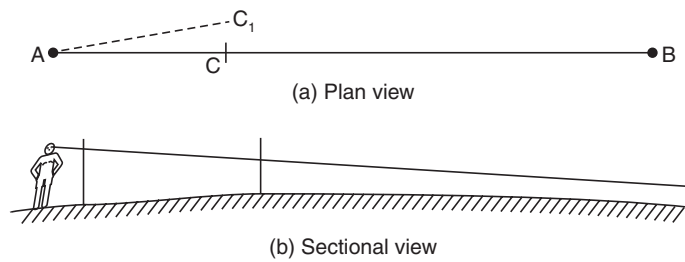


Fig. 12.18. Direct ranging

### 12.4.2 Indirect or Reciprocal Levelling

Due to intervening ground, if the ranging rod at B is not visible from station A, reciprocal ranging may be resorted. Figure 12.19 shows this scheme of ranging. It needs two assistants one at point M and another at point N, where from those points both station A and station B are visible. It needs one surveyor at A and another at B. To start with M and N are approximately selected, say  $M_1$  and  $N_1$ . Then surveyor near end A ranges person near M to position  $M_2$  such that  $AM_2N_1$  are in a line. Then surveyor at B directs person at N, to move to  $N_2$  such that  $BN_2M_2$  are in a line. The process is repeated till AMNB are in a line.

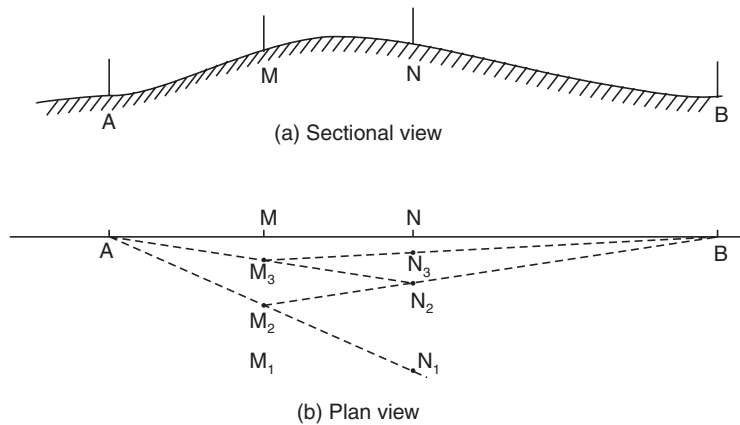


Fig. 12.19. Reciprocal ranging

## 12.5 OBSTACLES IN CHAINING

Though it is desirable to select stations so as to avoid obstacles, occasionally the obstacles are unavoidable.

Various obstacles to chaining may be grouped into:

- (i) Obstacles to ranging (chaining free-vision obstructed)
- (ii) Obstacles to chaining (chaining obstructed-vision free)
- (iii) Obstacles to both ranging and chaining.

Various methods of overcoming these obstacles are explained in this article.

### 12.5.1 Obstacles to Ranging

These obstacles can be further classified into the following categories:

(a) Both ends of the line are visible from some intermediate points. Intervening ground is an example of such obstacle. By resorting to reciprocal ranging this difficulty can be overcome.

(b) Both ends of the line may not be visible from intermediate points on the line, but may be visible from a point slightly away from the line. Intervening trees and bushes are the examples of such obstacles. This obstacle to chaining may be overcome by measuring along a random line as shown in Fig. 12.20. In this case required length

$$EB = \sqrt{EC^2 + CB^2}$$

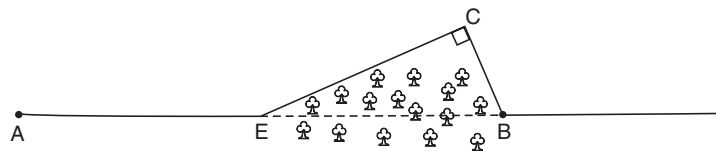


Fig. 12.20. Obstacle to ranging

### 12.5.2 Obstacles to Chaining

In this type the ends of lines are visible but chaining is obstructed. Examples of such obstructions are ponds, lakes, marshy land etc. Various geometric properties may be used to find obstructed length CB as shown in Fig. 12.21.

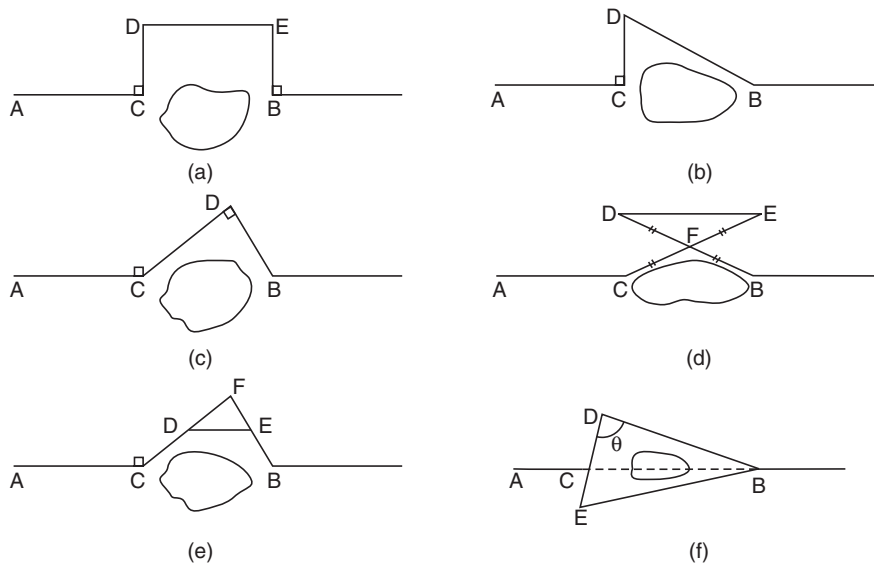


Fig. 12.21. Obstacles to chaining

(a) Set CD and BE perpendiculars to AB, such that CD = BE. Then

$$CB = DE \quad \text{[Fig. 12.22 (a)]}$$

(b) Set perpendicular CD to AB. Measure CD and DB. Then

$$CB = \sqrt{BD^2 - CD^2} \quad \text{[Fig. 12.22 (b)]}$$

(c) Set CD and DB such that DB ⊥ CD. Measure them. Then

$$CB = \sqrt{CD^2 + BD^2} \quad \text{[Fig. 12.22 (c)]}$$

(d) Select a convenient point F. Set FE = CF and FD = BF. Then

$$CB = DE \quad \text{[Fig. 12.22 (d)]}$$

(e) Select a convenient point F. Locate D and E such that CF = n DF and BF = n EF. Measure DE. Then,

$$\frac{CF}{DF} = \frac{BF}{EF} = n = \frac{CB}{DE}$$

$$\therefore CB = n DE \quad \text{[Fig. 12.22 (e)]}$$

(f) Select points D and E on line passing through C [Fig. 12.22 (b)]. Measure CD, CE, DB and EB.

Then, from ΔBDE,

$$\cos \theta = \frac{BD^2 + DE^2 - EB^2}{2BD \cdot DE} \quad \dots(a)$$

and from ΔBDC,

$$\cos \theta = \frac{CD^2 + BD^2 - CB^2}{2CD \cdot BD} \quad \dots(b)$$

From eqn. (a), cos θ can be found and substituting it in eqn. (b), the obstructed length CB can be found.

### 12.5.3 Obstacles to Both Chaining and Ranging

Building is a typical example of this obstacle. Referring to Fig. 12.22, line AB is to be continued beyond the obstacle, say as GH. Four possible methods are presented below:

(a) Set perpendiculars AC, BD such that AC = BD [Fig. 12.22 (a)]. Extend line CD to F. Drop perpendiculars EG and FH to line CF such that EG = FH = AC. GH is the continuation of line AB and DE = BG.

(b) Referring to Fig. 12.22 (b), set BC ⊥ to AB. Select D on extended line of AC. Set perpendicular DH such that AD = DH. Select point E on DH such that DE = DC. Then arcs of length EG = BC and arc of length HG = AB are drawn from E and H respectively and G is located. GH is continuation of AB and BG = CE.

(c) Referring to Fig. 12.22 (c), C is located such that AC = BC = AB. Extend AC to D and construct equilateral triangle DEF. Extend DF to H such that DH = DA. Locate convenient point I on

HD and construct equilateral triangle to locate G. Then GH is the continuation of line AB and length BG is given by

$$BG = AH - AB - GH = AD - AB - GH$$

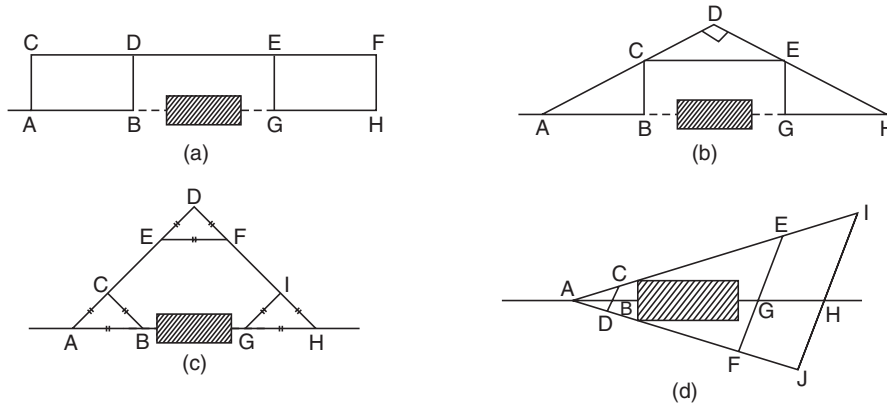


Fig. 12.22. Obstacles to both ranging and chaining

(d) In the method shown in Fig. 12.22 (d), points C and D are selected such that CBD is in a line. Extend AC to E and I such that  $AE = n \times AC$  and  $AI = m \times AC$ . Similarly Extend AD to F and J such that,  $AF = n \times AD$  and  $AJ = m \times AD$ . Locate G and H on lines EF and IJ such that,  $EG = n \times BC$  and  $IH = m \times BC$ . Then GH is the continuation of line AB. Now,

$$AG = n \times AB$$

$$\therefore BG = n \times AB - AB = (n - 1) AB$$

■ **Example 12.1:** In chaining past a pond, stations C and B were taken on the opposite sides of the pond. A line DCE was set by selecting  $CD = 220$  m and  $CE = 280$  m. The lines DB and ED which are on the opposite sides of the pond are measured. If  $DB = 500$  m and  $EB = 600$  m, find obstructed length CD.

**Solution:** Referring to Fig. 12.21 (f),

$$CD = 220 \text{ m} \qquad CE = 280 \text{ m}$$

$$DB = 500 \text{ m} \qquad EB = 600 \text{ m}$$

$$\therefore DE = DC + CE = 220 + 280 = 500 \text{ m}$$

From  $\triangle BDE$ ,

$$\cos \theta = \frac{DE^2 + BD^2 - EB^2}{2 DE \cdot BD} = \frac{500^2 + 500^2 - 600^2}{2 \times 500 \times 500} = 0.28$$

From  $\triangle BDC$ ,

$$\cos \theta = \frac{CD^2 + BD^2 - BC^2}{2 CD \cdot BD}$$

$$0.28 = \frac{220^2 + 500^2 - BC^2}{2 \times 220 \times 500}$$

$$61600 = 220^2 + 500^2 - BC^2$$

$$\therefore BC = 486.62 \text{ m Ans.}$$

## 12.6 ERRORS IN CHAINING

Errors in chaining may be classified as:

- (i) Personal errors
- (ii) Compensating errors, and
- (iii) Cumulating errors.

### 12.6.1 Personal Errors

Wrong reading, wrong recording, reading from wrong end of chain etc., are personal errors. These errors are serious errors and cannot be detected easily. Care should be taken to avoid such errors.

### 12.6.2 Compensating Errors

These errors may be sometimes positive and sometimes negative. Hence they are likely to get compensated when large number of readings are taken. The magnitude of such errors can be estimated by theory of **probability**. The following are the examples of such errors:

- (i) Incorrect marking of the end of a chain.
- (ii) Fractional part of chain may not be correct though total length is corrected.
- (iii) Graduations in tape may not be exactly same throughout.
- (iv) In the method of stepping while measuring sloping ground, plumbing may be crude.

### 12.6.3 Cumulative Errors

The errors, that occur always in the same direction are called cumulative errors. In each reading the error may be small, but when large number of measurements are made they may be considerable, since the error is always on one side. Examples of such errors are:

- (i) Bad ranging
- (ii) Bad straightening
- (iii) Erroneous length of chain
- (iv) Temperature variation
- (v) Variation in applied pull
- (vi) Non-horizontality
- (vii) Sag in the chain, if suspended for measuring horizontal distance on a sloping ground.

Errors (i), (ii), (vi) and (vii) are always +ve since they make measured length more than actual. Errors (iii), (iv) and (v) may be +ve or -ve.

## 12.7 TAPE CORRECTIONS

The following five corrections may be found for the measured lengths of tape:

- (i) Corrections for absolute length
- (ii) Corrections for pull
- (iii) Corrections for temperature
- (iv) Corrections for slope and
- (v) Corrections for sag.

### 12.7.1 Corrections for Absolute Length

Let,  $l$  = designated length of tape,  $l_a$  = actual length of tape.

Then correction for chain length

$$c = l_a - l$$

Hence, if the total length measured is  $L$ , the total correction

$$C_a = \frac{c}{l} L \quad \dots(12.2)$$

$\therefore$  Corrected length =  $L + C_a$

If  $A$  is the measured area with incorrect tape, the correct area

$$= \left(1 + \frac{c}{l}\right)^2 A = \left(1 + \frac{2c}{l}\right) A, \text{ since } C \text{ is small.} \quad \dots(12.3)$$

### 12.7.2 Corrections for Pull

If pull applied while standardising the length of tape and pull applied in the field are different, this correction is required.

Let,  $P_0$  = Standard pull

$P$  = Pull applied in the field

$A$  = Cross-sectional area of the tape

$L$  = Measured length of line.

$E$  = Young's modulus of the material of tape, then

$$C_p = \frac{(P - P_0) L}{AE} \quad \dots(12.4)$$

The above expression takes care of sign of the correction also.

### 12.7.3 Correction for Temperature

Let  $T_0$  = Temperature at which tape is standardised

$T_m$  = Mean temperature during measurement

$\alpha$  = Coefficient of thermal expansion of the material of the tape and

$L$  = Measured length,

Then the temperature correction  $C_t$  is given by,

$$C_t = L\alpha (T_m - T_0) \quad \dots(12.5)$$

The above expression takes care of sign of the correction also.

#### 12.7.4 Correction for Slope

If the length measured is 'L' and the difference in the levels of first and the last point is 'h', then slope correction

$$\begin{aligned} C_{sl} &= L - \sqrt{L^2 - h^2} \\ &= L [1 - \sqrt{1 - (h/2)^2}] \\ &= L \left[ 1 - \left( 1 - \frac{h^2}{2L^2} - \frac{h^4}{8L^4} \dots \right) \right] \\ &= \frac{h^2}{2L} \quad \dots(12.6) \end{aligned}$$

If measured length is L and slope is 'θ', then

$$C_{sl} = L - L \cos \theta = L (1 - \cos \theta) \quad \dots(12.7)$$

This correction is always -ve.

#### 12.7.5 Correction for Sag

While measuring on unevenly sloping ground, tapes are suspended at shorter length and horizontal distances are measured. This technique eliminates errors due to measurement along slopes, but necessitates correction for sag [Fig. 12.23]. Hence, measured length is more than actual length. Thus the correction is -ve. The correction, which is difference between the length of catenary and true length is given by

$$C_s = \frac{1}{24} \left( \frac{W}{P} \right)^2 L \quad \dots(12.8)$$

where,  $W$  = the weight of the tape of span length

$P$  = the pull applied

and  $L$  = measured length

It may be noted that if pull is more than standard pull, the correction for pull is +ve, while correction for sag is always -ve. The pull for which these two corrections neutralise each other is called 'normal tension'. Hence normal tension  $P_n$  may be found as,

$$C_p = C_s$$



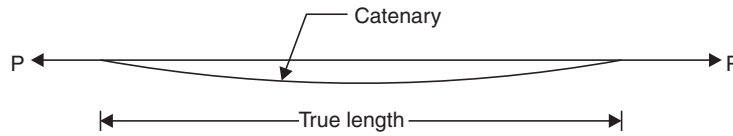


Fig. 12.23

$$\frac{(P_n - P_0) L}{AE} = \frac{1}{24} \left( \frac{W}{P_n} \right)^2 L$$

$$(P_n - P_0) P_n^2 = \frac{1}{24} W^2 AE$$

or

$$P_n = \frac{0.204 W \sqrt{AE}}{\sqrt{P_n - P_0}} \quad \dots(12.9)$$

The value of  $P_n$  is to be determined by trial and error method.

■ **Example 12.2:** A distance of 1500 m was measured with a 20 m chain. After the measurement chain was found to be 80 mm longer. If the length of chain was perfectly correct while starting measurement, what is the true length of the line measured?

**Solution:** Average correction per chain length

$$c = \frac{0 + 80}{2} = 40 \text{ mm} = 0.04 \text{ m}$$

Chain length = 20 m

∴ Correction for measured length

$$C_a = L \frac{c}{l} = 1500 \frac{0.04}{20}$$

$$= 3.0 \text{ m}$$

∴ **True length** = 1500 + 3.0 = **1503 m** **Ans.**

■ **Example 12.3:** A survey was conducted with a 20 m chain and plan of the field was drawn to a scale of 1 cm = 5 m. The area of the plan was found to be 62.8 cm<sup>2</sup>. However when the chain was tested at the end of work, it was found to be 20.10 m. Assuming the length was exactly 20.0 m in the beginning of survey work, determine the true area of the field.

**Solution:** Initial length of the chain = 20 m

Length at the end of work = 20.1 m

$$\therefore \text{Average length of chain} = \frac{20 + 20.1}{2} = 20.05 \text{ m}$$

$$\therefore \text{Average correction per chain length} = 20.05 - 20.00 = 0.05 \text{ m}$$

$$\text{Measured area on plan} = 62.8 \text{ cm}^2$$

Scale 1 cm = 5 m

$$\begin{aligned} \therefore \text{Measured area on field} &= 62.8 \times 5^2 \\ &= 1570 \text{ m}^2 \end{aligned}$$

$$\therefore \text{Corrected area on the ground} = A \left( \frac{l^1}{l} \right)^2 = 1570 \left( \frac{20.05}{20.00} \right)^2 = 1577.860 \text{ m}^2 \quad \text{Ans.}$$

■ **Example 12.4:** A 20 m tape was used for measuring a line at an average temperature of 65° F. The measured distances on the ground and slope of the ground are as given below:

2°	18'	for	125 m
3°	30'	for	250 m
1°	42'	for	a distance of 170 m

If the temperature at which tape was standardised is 80° F, find the true length of the line. Take  $\alpha = 6.2 \times 10^{-6}/^\circ\text{F}$ .

**Solution:** Measured horizontal distance =  $\Sigma L \cos \theta$

$$\begin{aligned} &= 125 \cos 2^\circ 18' + 250 \cos 3^\circ 30' + 170 \cos 1^\circ 42' \\ &= 544.367 \text{ m} \end{aligned}$$

Temperature correction

$$\begin{aligned} C_t &= L\alpha (T_m - T_0) \\ &= 544.367 \times 6.2 \times 10^{-6} (65 - 80) \\ &= -0.051 \text{ m} \end{aligned}$$

**Correct horizontal length**

$$= 544.367 - 0.051 = 544.316 \text{ m} \quad \text{Ans.}$$

■ **Example 12.5:** To measure a base line, a steel tape 30 m long, standardised at 15° C with a pull of 80 N was used. Find the correction per tape length, if the temperature at the time of measurement is 25° C and the pull exerted is 150 N.

Take Young's modulus  $E = 2 \times 10^5 \text{ N/mm}^2$  and coefficient of thermal expansion  $\alpha = 11.2 \times 10^{-6}/^\circ\text{C}$ . Cross-sectional area of tape is 8 mm<sup>2</sup>.

**Solution:**  $l = 30 \text{ m}$ ,  $\alpha = 11.2 \times 10^{-6}/^\circ\text{C}$ ,  $T_0 = 15^\circ\text{C}$ ,  $P_0 = 80 \text{ N}$   
 $T_m = 25^\circ\text{C}$ ,  $P = 150 \text{ N}$

∴ Correction for temperature

$$\begin{aligned} C_t &= l \alpha (T_m - T_0) \\ &= 30 \times 11.2 \times 10^{-6} (25 - 15) \\ &= 3.360 \times 10^{-3} \text{ m} \end{aligned}$$

Correction for pull

$$C_p = \frac{(P - P_0)l}{AE}$$

$$= \frac{(150 - 80) \times 30}{2 \times 10^5 \times 8}$$

$$= 1.3125 \times 10^{-3} \text{ m}$$

[Note: Unit of AE comes out to be Newton only, if A is in cm<sup>2</sup> or mm<sup>2</sup> and E in N/cm<sup>2</sup> or N/mm<sup>2</sup>].

∴ Total correction for temperature and pull

$$= C_t + C_p = 3.360 \times 10^{-3} + 1.3125 \times 10^{-3}$$

$$= 4.6725 \times 10^{-3} \text{ m per chain length}$$

■ **Example 12.6:** Calculate sag correction for a 30 m steel tape under a pull of 80 N, if it is suspended in three equal spans. Unit weight of steel is 78.6 kN/m<sup>3</sup>. Area of cross-section of tape is 8 mm<sup>2</sup>.

**Solution:** Length of each span = 10 m

$$W = \text{wt. of taper per span length}$$

$$= 78.6 \times 10 \times (8 \times 10^{-6})$$

$$= 6288 \times 10^{-6} \text{ kN} = 6.288 \text{ N}$$

[Note: 1 mm<sup>2</sup> = (0.001)<sup>2</sup> m<sup>2</sup> = 1 × 10<sup>-6</sup> m<sup>2</sup>]

$$P = 80 \text{ N} \quad L = 10 \text{ m}$$

∴ Correction for each span

$$= \frac{1}{24} \left( \frac{6.288}{80} \right)^2 \times 10$$

$$= 2.574 \times 10^{-3} \text{ m}$$

∴ Correction for three spans

$$= 3 \times 2.574 \times 10^{-3} \text{ m}$$

$$= 7.722 \times 10^{-3} \text{ m Ans.}$$

■ **Example 12.7:** A 30 m steel tape was standardised under 60 N pull at 65° F. It was suspended in 5 equal span during measurement. The mean temperature during measurement was 90° F and the pull exerted was 100 N. The area of the cross-section of the tape was 8 mm<sup>2</sup>. Find the true length of the tape, if,

$$\alpha = 6.3 \times 10^{-6}/^\circ\text{F}, E = 2 \times 10^5 \text{ N/mm}^2 \text{ and unit weight of steel} = 78.6 \text{ kN/m}^3.$$

**Solution:** Correction for temperature:

$$C_t = l \alpha (T_m - T_0)$$

$$= 30 \times 6.3 \times 10^{-6} (90 - 65)$$

$$= 4.725 \times 10^{-3} \text{ m}$$

Correction for pull:

$$C_p = \frac{(P - P_0)l}{AE} = \frac{(100 - 60) \times 30}{8 \times 2 \times 10^5} = 0.75 \times 10^{-3} \text{ m}$$

Correction for sag:

$$\text{Each span length} = \frac{30}{5} = 6 \text{ m}$$

$$\begin{aligned} \text{Weight of tape per span, } W &= 78.6 \times 6 \times 8 \times 10^{-6} \\ &= 3772.8 \times 10^{-6} \text{ kN} \\ &= 3.7728 \text{ N} \end{aligned}$$

∴ Correction for sag per span

$$\begin{aligned} &= \frac{1}{24} \left( \frac{3.7728}{100} \right)^2 \times 6 \\ &= 0.3559 \times 10^{-3} \text{ m} \end{aligned}$$

∴ Corrections for 5 spans

$$\begin{aligned} C_s &= 5 \times 0.3559 \times 10^{-3} \\ &= 1.779 \times 10^{-3} \text{ m (-ve)} \end{aligned}$$

Noting that correction  $C_t$  and  $C_p$  are +ve, while correction  $C_s$  is -ve, we get

$$\begin{aligned} \text{Total correction} &= 4.725 \times 10^{-3} + 0.75 \times 10^{-3} - 1.779 \times 10^{-3} \\ &= 3.696 \times 10^{-3} \text{ m} \\ &= 3.696 \text{ mm} \end{aligned}$$

∴ **True length of tape**

$$\begin{aligned} &= 30 + 3.696 \times 10^{-3} \\ &= \mathbf{30.003696 \text{ m Ans.}} \end{aligned}$$

## 12.8 CONVENTIONAL SYMBOLS

IS 962—1989, ‘code of practice for architectural and building drawings’ has specified standard symbols for various objects as shown in Table 12.1 on next page.

If coloured plans are to be made, the code recommends light washes of the following shades:

For roads – Burnt sienna

For buildings – Light grey

For compound walls – Indigo

For water – Borders edged with Prussian blue

For trees – Green.

Table 12.1

Chain line		Road under railway	
Triangulation station		Boundaries without pillars	
Traverse station		Boundaries with pillars	
Building		Township or taluka boundaries	
Shed with open side		River	
Shed with closed side		Pond	
Temple, mosque and church		Electric line	
Path		Tree	
Unfenced road		Orchard	
Fenced road		Woods	
Railway line: Single		Grass	
Railway line: Double		Cutting	
Road bridge		Embankment	
Level crossing		North line	
Road over railway			

## QUESTIONS

1. Briefly explain the various approximate methods of measurement of distances.
2. Briefly explain features of metric chain.
3. Distinguish between metallic tape and steel tape.
4. Write short notes on
  - (i) Steel band
  - (ii) Ranging rods
  - (iii) Invar tape
  - (iv) Line ranger.
5. Explain the terms
  - (i) Check line and tie line
  - (ii) Reference sketch.
6. List the various points to be considered in selecting stations for surveying.
7. Explain the use and working of
  - (i) Open cross staff
  - (ii) Prism square.
8. Explain the method of reciprocal levelling. When do you need it?
9. Explain any two methods of overcoming chaining problem in the following cases:
  - (i) the obstruction is in the form of a pond.
  - (ii) the obstruction is in the form of a building.
10. There is an obstacle in the form of a pond on the main chain line AB. Two points C and D were taken on the opposite sides of the pond. On the left of CD, a line CE was laid out 65 m in length and a second line CF of 85 long was laid on the right of CD such that ECF are in a line. Determine the obstructed length CD. Given ED = 110 m and DF = 120 m. [Ans. CD = 87.015 m]
11. Distinguish between cumulative error and compensating errors. Give examples for each case.
12. A 30 m tape used for measuring a line was found to be 30.01m at the beginning and 30.026 m at the end of the work. The area of plan drawn to a scale 1:1000 was found to be 5625 mm<sup>2</sup>. Compute the correct area of the field. [Ans. 5631.752 m<sup>2</sup>]
13. A steel tape 30 m long, standardised at 18°C at a pull of 100 N was used. Find the correction per tape length, if the temperature at the time of measurement is 24°C and the pull exerted is 140 N. Cross-sectional area of the tape is 8 mm<sup>2</sup>. Take  $E = 2 \times 10^5 \text{ N/mm}^2$  and  $\alpha = 11.2 \times 10^{-6} /^\circ\text{C}$ . Tape was stretched over 4 equal spans. If measured length is 200 m, what is the actual length? Take unit weight of steel = 78.6 kN/m<sup>3</sup>. [Ans. L = 199.979 m]
14. With neat sketches indicate conventional symbol used for the following objects in surveying:
  - (i) Building
  - (ii) Double line railway track
  - (iii) Cultivated land
  - (iv) Temple, mosque and church
  - (v) River.

## Compass Surveying

Disadvantage of chain surveying is that, in it only distances are measured and hence area is to be covered with a network of triangles. If the length as well as angle of a line can be measured with respect to a known direction then it is possible to plot a line, independent of length of other lines. Hence, in such cases there is no compulsion of going for a network of triangles only. Compass is an instrument which can be used to measure the direction of a survey line with respect to magnetic north-south. The magnetic north-south direction which is the reference direction is called **meridian** (reference direction) and the angle between the line and the meridian is called **bearing**. Use of compass for measuring direction of a line simplifies the surveying to a great extent.

In this chapter construction of different types of compasses, the system of noting bearings of the lines, some problems associated with measurement with compass are explained and then field work involved in compass survey is presented.

### 13.1 TYPES OF COMPASS

The types of compass that are used commonly are: (i) prismatic compass; and (ii) surveyor compass. The essential parts of both type are:

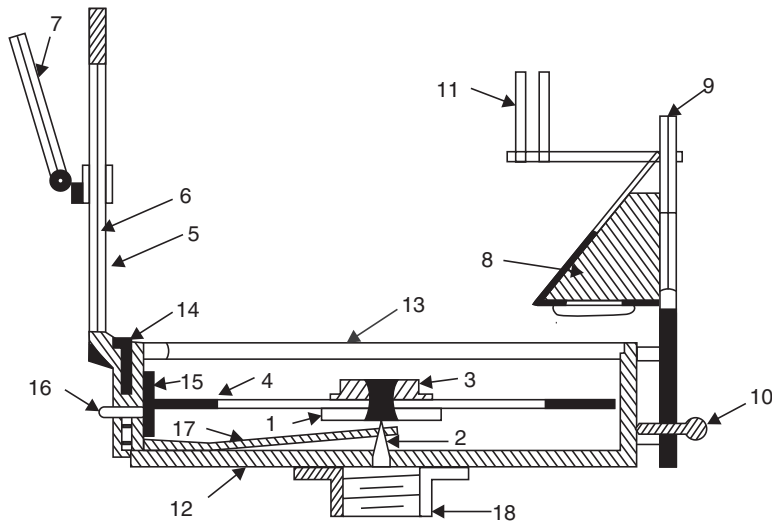
- (i) a magnetic needle,
- (ii) a graduated circle,
- (iii) a line of sight, and
- (iv) a box to house them.

There are some differences in the essential parts of the two type of compass. The construction of the two types of compass is explained and the difference in them is pointed out in this article.

#### 13.1.1 Prismatic Compass

Figure 13.1 shows the cross-section of a typical prismatic compass [see plate 13.1 also].

A magnetic needle of broad form (1) is balanced on a hard and pointed steel pivot (2). The top of the pointed pivot is protected with agate cap (3).



- |                              |                              |
|------------------------------|------------------------------|
| 1. Needle                    | 10. Focussing stud           |
| 2. Pivot                     | 11. Dark sunglasses          |
| 3. Agate cap                 | 12. Box                      |
| 4. Graduated disc            | 13. Glass cover              |
| 5. Slit metal frame          | 14. Lifting pin              |
| 6. Horse hair                | 15. Light spring             |
| 7. Mirror                    | 16. Brake pin or knob        |
| 8. Reflecting prism with cap | 17. Lifting lever            |
| 9. Eye vane                  | 18. Support to fit on tripod |

**Fig. 13.1.** Prismatic compass



**Plate 13.1** Prismatic compass

An aluminium graduated disk (4) is fixed to the top of the needle. The graduations are from zero to 360° in clockwise direction when read from top. The direction of north is treated as zero degrees, east as 90°, south as 180° and west as 270°. However, while taking the readings observations are at the other end of line of sight. Hence, the readings are shifted by 180° and graduations are marked as shown in Fig. 13.2. The graduations are marked inverted because they are read through a prism.



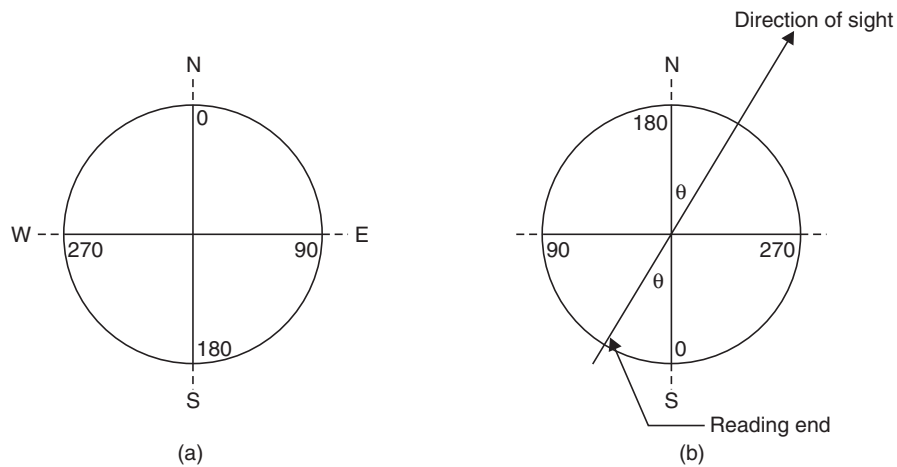


Fig. 13.2

The line of sight consists of object unit and the reading unit. Object unit consists of a slit metal frame (5) hinged to the box. In the centre the slit is provided with a horse hair or a fine wire or thread (6). The metal frame is provided with a hinged mirror (7), which can be placed upward or downward on the frame. It can be slid along the frame. The mirror can be adjusted to view objects too high or too low from the position of compass. Reading unit is provided at diametrically opposite edge. It consists of a prism (8) with a sighting eye vane (9). The prism magnifies the readings on the graduation disk just below it. For focussing, the prism is lowered or raised on the frame carrying it and then fixed with the stud (10). Dark sunglasses (11) provided near the line of sight can be interposed if the object to be sighted is bright (*e.g.*, sun).

The bottom of the box (12) which is about 85 mm to 110 mm supports the pivot of needle firmly at its centre. The object vane and the prism are supported on the sides of the box. The box is provided with a glass (13) lid which protects the graduation disc at the same time permit the direct reading from the top. When the object vane is folded on the glass top it presses a lifting pin (14) which activates lifting lever (15) lifts the needle off the pivot. Thus, it prevents undue wear of pivot point. While taking reading, if graduation disc vibrates, it can be dampened with a spring (16). For pressing spring a knob or brake pin (17) is provided on the box. When not in use prism can be folded over the edge of the box. The box is provided with a lid to close it when the compass is not in use. The box is provided with a socket to fit it on the top of a tripod.

### 13.1.2 Surveyors Compass

In this type of compass graduation disc is fixed to the box and magnetic needle is free to rotate above it. There is no prism provided at viewing end, but has a narrow slit. After fixing the line of sight, the reading is directly taken from the top of the glass cover. Hence, graduations are written directly (not inverted). In this compass graduations are from zero to 90°, zero being to north or south and 90° being to east and west. An angle of 20° to north direction to the east is written as N 20° E, and an angle of 40° to east from south is written as S 40° E. Always first direction indicated is north or south and the last letter indicates east or west direction. In this system graduated circle rotates with line of sight and magnetic needle is always towards north. The reading is taken at the tip of needle. Hence, on the compass east and west are marked interchanged and marked [Ref. Fig. 13.3] Plate 13.2 shows the photograph of a surveyors compass.

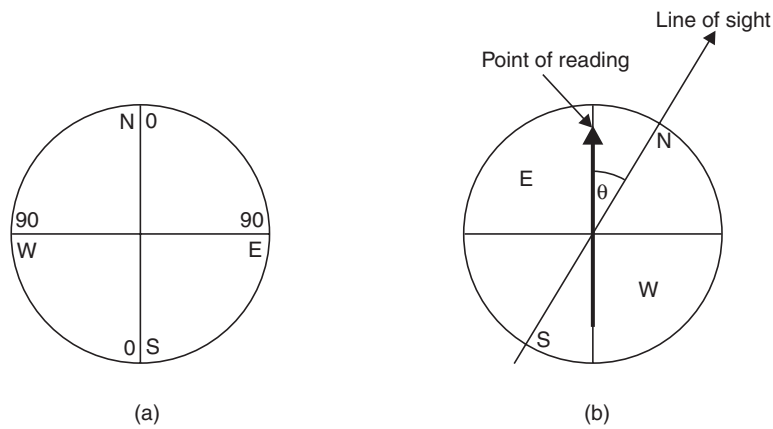


Fig. 13.3

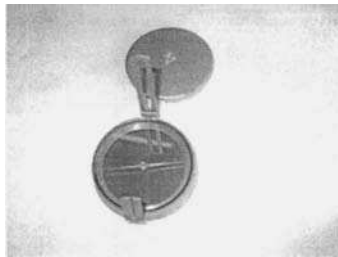


Plate 13.2 Surveyor's compass

**Difference Between Prismatic Compass and Surveyors Compass**

The difference between prismatic and surveyor's compass are listed in Table 13.1.

**Table 13.1.** Differences between prismatic and surveyors compass

Sr. No.	Prismatic Compass	Surveyors Compass
1.	Graduation circle is fixed to broad type needle. Hence, it will not rotate with the line of sight.	Graduation circle is fixed to the box. Hence, it rotates with the line of sight.
2.	There is a prism at viewing end.	At viewing end there is no prism. There is only a slit.
3.	Sighting and reading can be done simultaneously.	Sighting and viewing cannot be done simultaneously.
4.	The magnetic needle do not act as an index.	Magnetic needle acts as index while reading.
5.	The graduations are in whole circle bearing.	The graduations are in quadrantal system.
6.	Graduations are marked inverted since its reflection is read through prism.	Graduations are marked directly. They are not inverted.
7.	The reading is taken through a prism.	The reading is taken by directly viewing from top glass.
8.	Tripod may or may not be used. It can be held on a stretched hand also.	Tripod is essential for using it.

## 13.2 METHOD OF USING A COMPASS

To take a reading from a compass, the following *temporary adjustments* are required:

(i) *Centring*: The compass should be fixed to the stand and set over the station. To centre the compass legs of the tripod stand should be moved inward-outward or in a circumferential direction. To check centring plumb may be used or a pebble dropped from the centre of the compass.

(ii) *Levelling*: In compass survey perfect levelling is not necessary, but it should be sufficient to permit free suspension of magnetic needle. For checking levelling a bubble level is provided in many compasses. After centring bubble should be ensured in the middle of the circle provided for it in the level. If it is not within that circle, circumferential movements may be provided to the legs of tripod so that without disturbing centring the levelling is achieved.

(iii) *Focussing the prism*: In prismatic compass, to focus the prism on graduated circle, its attachment is slid up or down till the readings are clearly visible. There is no such requirement in surveyors compass.

The following steps are required for observing bearing of a line, say, *AB*:

- (i) Centre the compass over *A*.
- (ii) Level the compass.
- (iii) Focus the prism, if prismatic compass is used.
- (iv) Rotate the box till ranging rod at *B* is sighted through the line of sight.
- (v) Bring the needle to rest using knob.
- (vi) Take the reading and note it in the field book.

Care should be taken to see that the line of sight is not disturbed between the line of sighting the object and the time of reading the bearing.

## 13.3 BEARING

As stated earlier a bearing of a line is the angle made by the line with respect to a reference direction, the reference direction being known as meridian. The direction shown by a freely suspended and properly balanced magnetic needle is called **magnetic meridian** and the horizontal angle made by a line with this meridian is known as **magnetic bearing**.

The points of intersection of earth's axis with surface of the earth are known as geographic north and south pole. The line passing through geographic north, south and the point on earth is called **true meridian** at that point and the angle made by a line passing through that point is called **true bearing**.

While traversing along lines *A, B, C, D ...*, the bearing of line *AB* is called **fore bearing of AB** and the bearing of *BA* is called **back bearing**. Fore bearing and back bearing differ by  $180^\circ$ .

## 13.4 WHOLE CIRCLE BEARING AND REDUCED BEARING

In whole circle bearing (**WCB**) the bearing of a line at any point is measured with respect to a meridian. Its value varies from zero to  $360^\circ$ , increasing in clockwise direction. Zero is north direction,  $90^\circ$  is east,



(iv) Since it is in NW quadrant,

$$32^\circ 42' = 360^\circ - \theta$$

or

$$\theta = 360^\circ - 32^\circ 42' = 327^\circ 18'$$

**Ans.**

■ **Example 13.2:** The following fore bearings were observed for lines, AB, BC, CD, DE, EF and FG respectively. Determine their back bearings:

(i)  $148^\circ$

(ii)  $65^\circ$

(iii)  $285^\circ$

(iv)  $215^\circ$

(v) N  $36^\circ$  W

(vi) S  $40^\circ$  E

**Solution:** The difference between fore bearing and the back bearing of a line must be  $180^\circ$ . Noting that in WCB angle is from  $0^\circ$  to  $360^\circ$ , we find back bearing = fore bearing  $\pm 180^\circ$

+  $180^\circ$  is used if  $\theta$  is less than  $180^\circ$  and

–  $180^\circ$  is used when  $\theta$  is more than  $180^\circ$ .

Hence

(i) BB of AB =  $145^\circ + 180^\circ = 325^\circ$

(ii) BB of BC =  $65^\circ + 180^\circ = 245^\circ$

(iii) BB of CD =  $285^\circ - 180^\circ = 105^\circ$

(iv) BB of DE =  $215^\circ - 180^\circ = 35^\circ$

In case of RB, back bearing of a line can be obtained by interchanging N and S at the same time E and W. Thus

(v) BB of EF = S  $36^\circ$  E

(vi) BB of FG = N  $40^\circ$  W.

### 13.5 COMPUTATION OF ANGLES

At any point, if bearings of any two lines are known, the angle between these two lines can be easily found by drawing a neat sketch, and then noting the difference. The procedure is illustrated with the examples given below.

■ **Example 13.3:** In a closed traverse the following bearings were observed with a compass. Calculate the interior angles.

Line	Fore bearing
AB	$65^\circ 00'$
BC	$125^\circ 30'$
CD	$200^\circ 00'$
DE	$265^\circ 15'$
EA	$330^\circ 00'$

**Solution:** Figure 13.5 shows the angles observed. Back bearings of all the lines may be worked out and noted on the figure. Then calculation of interior angles can be easily carried out.

Line	Fore bearing	Back bearing
AB	65° 00'	245° 00'
BC	125° 30'	305° 30'
CD	200° 00'	20° 00'
DE	265° 15'	85° 15'
EA	330° 00'	150° 00'

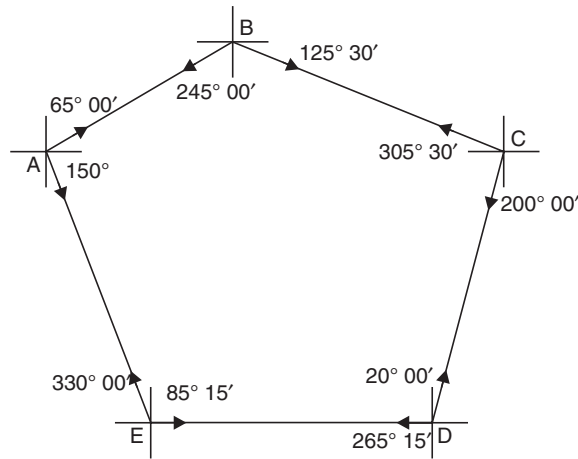


Fig. 13.5

Referring to figure:

$$\angle A = 150^\circ 00' - 65^\circ 00' = 85^\circ 00'$$

$$\angle B = 245^\circ 00' - 125^\circ 30' = 119^\circ 30'$$

$$\angle C = 305^\circ 30' - 200^\circ 00' = 105^\circ 30'$$

$$\angle D = (360^\circ - 265^\circ 15') + 20^\circ 00' = 114^\circ 45'$$

$$\angle E = (360^\circ - 330^\circ 00') + 85^\circ 15' = 115^\circ 15'$$

■ **Example 13.4.** The angles observed with a surveyor compass in traversing the lines AB, BC, CD, DE and EF are as given below. Compute the included angles and show them in a neat sketch.

Line	Fore bearing
AB	N 55° 30' E
BC	S 63° 30' E
CD	N 70° 00' E
DE	S 45° 30' E
EF	N 72° 15' E

**Solution:** Figure 13.6 shows this traverse. First back bearings of all lines are calculated and noted in the table shown below:

Line	FB	BB
AB	N 55° 30' E	S 55° 30' W
BC	S 63° 30' E	N 63° 30' W
CD	N 70° 00' E	S 70° 00' W
DE	S 45° 30' E	N 45° 30' W
EF	N 72° 15' E	S 72° 15' W.

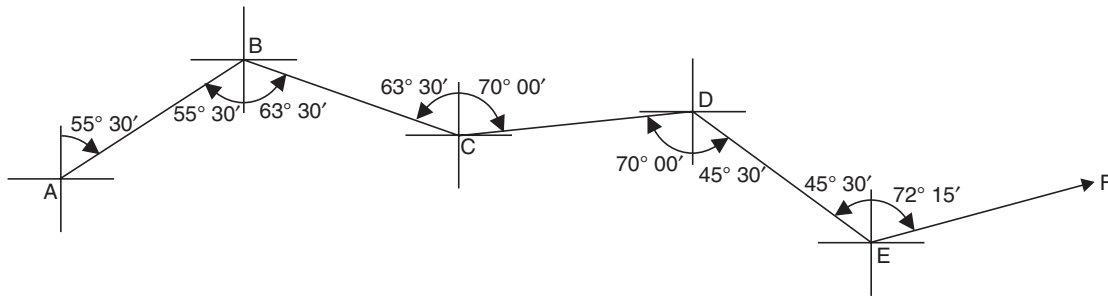


Fig. 13.6

Referring to the figure, we find

$$\angle B = 55^\circ 30' + 63^\circ 30' = 119^\circ 00' \quad \text{Ans.}$$

$$\angle C = 63^\circ 30' + 70^\circ 00' = 133^\circ 30' \quad \text{Ans.}$$

$$\angle D = 70^\circ 00' + 45^\circ 30' = 115^\circ 30' \quad \text{Ans.}$$

$$\angle E = 45^\circ 30' + 72^\circ 15' = 117^\circ 45' \quad \text{Ans.}$$

### 13.6 DECLINATION AND DIP

The magnetic meridian and the true meridian may not coincide with each other in a place. The horizontal angle between these two meridians is known as **magnetic declination**. The magnetic north at a place may be towards east or west of true north (Fig. 13.7). If it is towards east, it is known as eastern or +ve declination. Western declination is known as -ve declination. Eastern declination is to be added to observed magnetic bearings to get true meridian. To find magnetic declination at a point true meridian should be established from astronomical observations and magnetic meridian by a compass. Maps are made with respect to true meridian.

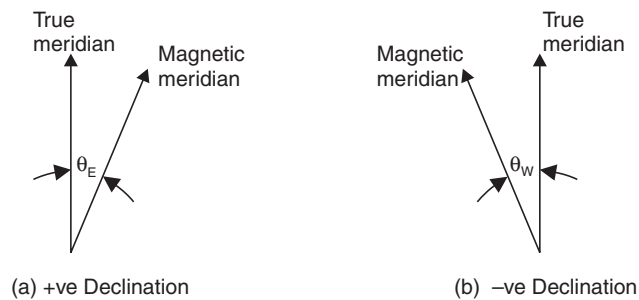


Fig. 13.7. Magnetic declination

Magnetic declination varies from time to time and also from place to place. In the noon sun is exactly on the geographical meridian. In India, 'Survey of India' department conducts astronomical survey and publishes **Isogonic Charts** from which magnetic declinations at any point can be found. The lines joining the points at which declination is the same at the given time are called '**Isogonic Lines**'. Lines joining points of zero declinations are called '**Agonic Lines**'. The isogonic lines are quite irregular near geographic poles. The isogonic charts show lines of equal annual change in declination.

The following type of variations are observed in declination:

- (i) Secular variation,
- (ii) Annual variation,
- (iii) Daily variations, and
- (iv) Irregular variations.

### 13.6.1 Secular Variation

The magnetic meridian swings like a pendulum to the left and to the right of true meridian. Its period of variation is approximately 250 years.

### 13.6.2 Annual Variation

It is observed that in a year declination varies from 1' to 2'.

### 13.6.3 Daily Variation

The daily variation of magnetic declination is as much as 10'. This variation is also known as '**Dirunal Variation**'. The following factors influence its magnitude:

- (a) It is more in day and less in night.
- (b) It is more in summer and less in winter.
- (c) The amount of variation changes from year to year.
- (d) It is more near magnetic poles and less near equator.

### 13.6.4 Irregular Variation

Due to earthquakes and volcanic eruptions, magnetic storms occur, resulting into changes in magnetic meridian. Such changes are from 1° to 2°.

### Magnetic Dip

A perfectly balanced, freely suspended magnetic needle dips towards its northern end in northern hemisphere and towards its southern end in southern hemisphere. If it is at north pole, the needle takes



vertical position. The vertical angle between the horizontal and the direction shown by a perfectly balanced and freely suspended needle is known as the magnetic dip at that place. Its value is  $0^\circ$  at equator and  $90^\circ$  at magnetic poles. To counteract the dip, a sliding rider (weight) is provided on the needle.

■ **Example 13.5:** True bearing of line AB is  $357^\circ$  and its magnetic bearing is  $1^\circ 30'$ . Determine the declination. Also find the true bearing of AC which has magnetic bearing equal to  $153^\circ 30'$ .

**Solution:** [Ref. Fig. 13.8]

**Magnetic Declination** =  $1^\circ 30' + (360^\circ - 357^\circ) = 4^\circ 30'$ , west. Magnetic bearing of AC =  $153^\circ 30'$ .

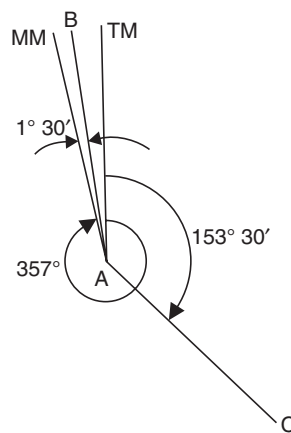


Fig. 13.8

$$\begin{aligned} \therefore \text{ True bearing of AC} &= 153^\circ 30' - 4^\circ 30' \\ &= 149^\circ \quad \text{Ans.} \end{aligned}$$

■ **Example 13.6:** In an old map line AB was drawn with a magnetic bearing of  $136^\circ 45'$  when the magnetic declination was  $2^\circ 30'$  east. To what magnetic bearing the line should be set now, if magnetic declination is  $3^\circ 30'$  west?

**Solution:** Referring to Fig. 13.9, it is clear that

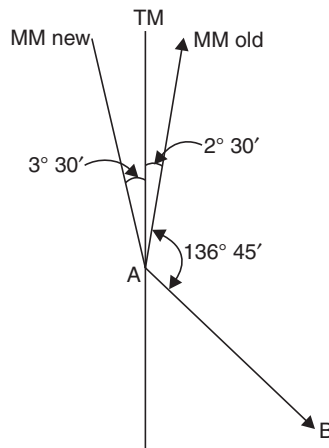


Fig. 13.9

**Present magnetic bearing of line AB**

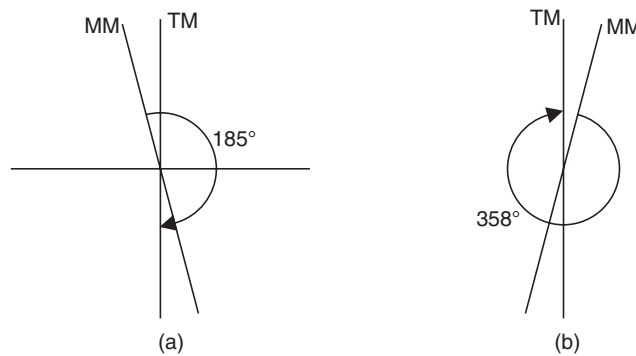
$$= 3^\circ 30' + 2^\circ 30' + 136^\circ 45'$$

$$= 142^\circ 45'$$

**Ans.**

■ **Example 13.7:** Find the declination at a place, if the magnetic bearing to the sun at noon is (a)  $185^\circ$  (b)  $358^\circ$ .

**Solution:** (a) Referring to Fig. 13.10 (a), since the magnetic bearing to the sun in the noon is  $185^\circ$ , it is to the geographic south pole. Hence, to the magnetic bearing to north pole is  $5^\circ$ , i.e., **declination is  $5^\circ$ .** **Ans.**



**Fig. 13.10**

(b) Referring to Fig. 13.10 (b),

**Declination =  $360^\circ - 358^\circ = 2^\circ$  East.**

### 13.7 LOCAL ATTRACTION

A freely suspended and properly balanced magnetic needle is expected to show magnetic meridian. However, local objects like electric wires and objects of steel attract magnetic needle towards themselves. Thus, needle is forced to show slightly different direction. This disturbance is called local attraction. The list of materials which cause local attraction are:

- (i) magnetic rock or iron ore,
- (ii) steel structures, iron poles, rails, electric poles and wires,
- (iii) key bunch, knife, iron buttons, steel rimmed spectacles, and
- (iv) chain, arrows, hammer, clearing axe etc.

Surveyor is expected to take care to avoid local attractions listed in (iii) and (iv) above.

#### Detecting Local Attraction

For detecting local attraction it is necessary to take both fore bearing and back bearing for each line. If the difference is exactly  $180^\circ$ , the two stations may be considered as not affected by local attraction. If difference is not  $180^\circ$ , better to go back to the previous station and check the fore bearing. If that reading is same as earlier, it may be concluded that there is local attraction at one or both stations.

### Correcting Observed Bearings

If local attraction is detected in a compass survey observed bearings may be corrected by any one of the following two methods:

**Method I:** It may be noted that the included angle is not influenced by local attraction as both readings are equally affected. Hence, first calculate included angles at each station, commencing from the unaffected line and using included angles, the corrected bearings of all lines may be calculated.

**Method II:** In this method, errors due to local attraction at each of the affected station is found starting from the bearing of a unaffected local attraction, the bearing of the successive lines are adjusted.

These methods are illustrated with the examples below:

■ **Example 13.8:** In a closed traverse, the following bearings were observed, with a compass. Calculate their interior angles and then compute the corrected magnetic bearings:

Line	FB	BB
AB	46° 30'	226° 30'
BC	118° 30'	300° 15'
CD	210° 00'	28° 00'
DE	271° 15'	93° 15'
EA	313° 45'	132° 00'

**Solution:** Figure 13.11 shows the traverse. Difference between FB and BB of line AB is exactly 180°. Hence, stations A and B are not affected by local attractions. Hence, all the bearings taken from stations A and B are correct magnetic bearings.

Correct bearing of AB = 46° 30'

Correct bearing of BA = 226° 30'

From the figure,

$$\angle A = 132^\circ 00' - 46^\circ 30' = 85^\circ 30'$$

$$\angle B = 226^\circ 30' - 118^\circ 30' = 108^\circ 00'$$

$$\angle C = 300^\circ 15' - 210^\circ 00' = 90^\circ 15'$$

$$\angle D = (360^\circ - 271^\circ 15') + 28^\circ 00' = 116^\circ 45'$$

$$\angle E = (360^\circ 00' - 313^\circ 45') + 93^\circ 15' = 139^\circ 30'$$

$$\begin{aligned} \text{Total Interior Angle} &= \angle A + \angle B + \angle C + \angle D + \angle E \\ &= 540^\circ 00'. \end{aligned}$$

Hence there is no observations error.

[Note: In a pentagon sum of interior angles =  $(2n - 4) \times 90 = (2 \times 5 - 4) \times 90 = 540^\circ$ . If there is observation error it is to be distributed equally to all interior angles].

Since, stations A and B are not affected by local attraction, correct bearings are:

$$\text{Bearing of AB} = 46^\circ 30'$$

$$\text{Bearing of BA} = 46^\circ 30' + 180^\circ 00' = 226^\circ 30'$$

$$\begin{aligned} \text{Bearing of BC} &= 226^\circ 30' - \angle B = 226^\circ 30' - 108^\circ 00' = 118^\circ 30' \\ \text{Bearing of CB} &= 118^\circ 30' + 180^\circ 00' = 298^\circ 30' \\ \text{Bearing of CD} &= 298^\circ 30' - \angle C = 298^\circ 30' - 90^\circ 15' = 208^\circ 15' \\ \text{Bearing of DC} &= 208^\circ 15' - 180^\circ 00' = 28^\circ 15' \\ \text{Bearing of DE} &= 28^\circ 15' - \angle D = 28^\circ 15' - 116^\circ 45' \\ &= -89^\circ 30' = -88^\circ 30' + 360^\circ 00' = 271^\circ 30' \\ \text{Bearing of ED} &= 271^\circ 30' - 180^\circ 00' = 91^\circ 30' \\ \text{Bearing of EA} &= 91^\circ 30' - \angle E = 90^\circ 30' - 139^\circ 30' \\ &= -48^\circ 00' = -48^\circ 00' + 360^\circ = 312^\circ 00' \\ \text{Bearing of AE} &= 312^\circ 00' - 180^\circ 00' = 132^\circ 00' \end{aligned}$$

[Checked. It should be equal to the observed bearing, since station E is not affected].

■ **Example 13.9:** Solve problem no. 13.8 by the method of correction to local attraction.

**Solution:** [Ref. Fig. 13.11]

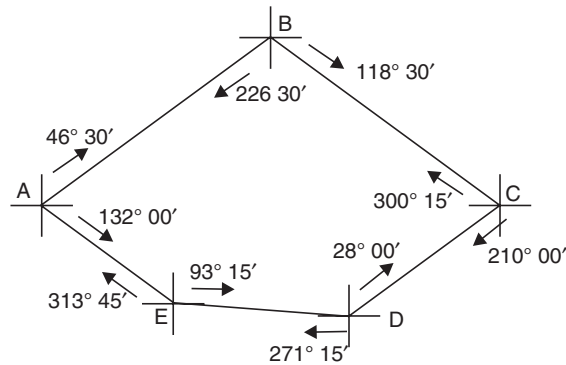


Fig. 13.11

Since, the difference between FB and BB of line AB is exactly  $180^\circ$ , stations A and B are not affected by local attraction. Hence, corrections to the observed bearings at A and B are zero.

$$\begin{aligned} \therefore \text{Correct bearing CB} &= 118^\circ 30' + 180^\circ 00' = 298^\circ 30' \\ \text{But observed bearing} &= 300^\circ 15' \\ \text{Hence correction at station C} &= 298^\circ 30' - 300^\circ 15' = -1^\circ 45' \\ \therefore \text{Correct bearing of CD} &= 210^\circ 00' - 1^\circ 45' = 208^\circ 15' \\ \text{Correct bearing DC} &= 208^\circ 15' - 180^\circ 00' = 28^\circ 15' \\ \text{Observed bearing of DC} &= 28^\circ 00' \\ \therefore \text{Corrections required at D} &= 28^\circ 15' - 28^\circ 00' = 0^\circ 15' \\ \therefore \text{Correct bearing of DE} &= 271^\circ 15' + 0^\circ 15' = 271^\circ 30' \\ \text{Correct bearing of ED} &= 271^\circ 30' - 180^\circ 00' = 91^\circ 30' \end{aligned}$$

$$\begin{aligned} \text{But observed bearing of ED} &= 93^\circ 15' \\ \therefore \text{Correction for observations at E} &= 91^\circ 30' - 93^\circ 15' = -1^\circ 45' \\ \therefore \text{Correct bearing of EA} &= 313^\circ 45' - 1^\circ 45' = 312^\circ 00' \\ \therefore \text{Correct bearing of AE} &= 312^\circ 00' - 180^\circ 00' = 132^\circ 00'. \text{ [Checked]} \end{aligned}$$

The calculations may be carried out in tabular form as shown in Table 13.2.

**Table 13.2**

Station	Line	Observed Bearing	Correction	Correct Bearing
A	AE	132° 00'	0	132° 00'
	AB	46° 30'		46° 30'
B	BA	226° 30'	0	226° 30'
	BC	118° 30'		118° 30'
C	CB	300° 15'	-1° 45'	298° 30'
	CD	210° 00'		208° 15'
D	DC	28° 00'	0° 15'	28° 15'
	DE	271° 15'		271° 30'
E	ED	93° 15'	-1° 45'	91° 30'
	EA	313° 45'		312° 00'

[Note: Correction = Correct reading – Observed reading]

## 13.8 CHAIN AND COMPASS SURVEYING FIELD WORK

In compass survey chain or tape is used for linear measurement. If the surveying starts from a station, goes round an area and ends at the starting station it is called **closed traverse**. If survey starts from a point, goes along a number of interconnected lines and ends at some other point it is called as **open traverse**. Closed traverse is used for preparing plan of an area while open traverse is useful in the road, rail or canal projects. The following are required for chain and compass survey:

- (i) Compass and stand
- (ii) Chain and tape
- (iii) 10 arrows
- (iv) 5 to 6 ranging rods
- (v) Ranging poles
- (vi) Pegs and hammer
- (vii) Plumb bobs
- (viii) Line ranger, cross staff etc.

## Field Work

Field work involves:

- (i) reconnaissance survey
- (ii) preparation of location sketches of stations
- (iii) measurement of directions
- (iv) measurement of lengths and offsets, and
- (v) recording measurements.

(i) **Reconnaissance Survey:** The entire area to be surveyed is inspected to select survey stations. Important points to be considered in selecting stations are:

- (a) Adjacent stations should be intervisible.
- (b) Lines to be chained should be free of obstacles.
- (c) Number of survey lines should be minimum.
- (d) Survey lines should run close to the important objects, so that offset lengths are small.

An index map is prepared with pencil and stations are marked. If necessary, changes may be made in survey lines and corresponding changes in the index plan.

## Location Sketches

Before commencing surveying a line, the location sketches of the stations of that line should be prepared. At the beginning of the field book few pages should be reserved for drawing location sketches.

## Direction Measurement

The following precautions should be taken in measuring the direction of a survey line with compass.

- (a) Centre the compass on the station correctly.
- (b) Level the compass and ensure needle is free to move.
- (c) Take the reading only after vibration of graduation circle/needle is stopped. Use the knob, if necessary.
- (d) Gently tap the top of the glass of compass to remove sluggishness of the needle and take the reading after vibration stops.
- (e) While taking reading parallax should be avoided.
- (f) Care should be taken to keep away steel and iron objects like key bunch, metal framed spectacles, iron buttons, chain, arrows etc.
- (g) If handkerchief is used to clean top of glass of compass, the glass is charged with electricity. As a result of it local attraction is induced. To avoid this problem apply moist fingers to clean the glass.
- (h) If the compass is not in use, fold the prism and object vane on the top of glass plate, so that needle is lifted from the pivot to avoid unnecessary wear of the pivot.
- (i) For all survey lines fore bearings and back bearings should be taken. If any other survey station is visible, bearing should be taken to that station also, which helps in checking survey work.

**Measurement of Lengths and Offsets**

This is similar to the one used in chain survey. However, it may be noted that for the objects of less importance one can measure the bearing of the offset and its length.

**Recording Chain and Compass Measurements**

The type of field book used in chain survey is used in this survey also. Apart from recording linear measurements in this survey the bearings taken also should be recorded. Figure 13.12 shows a page of typical field record.

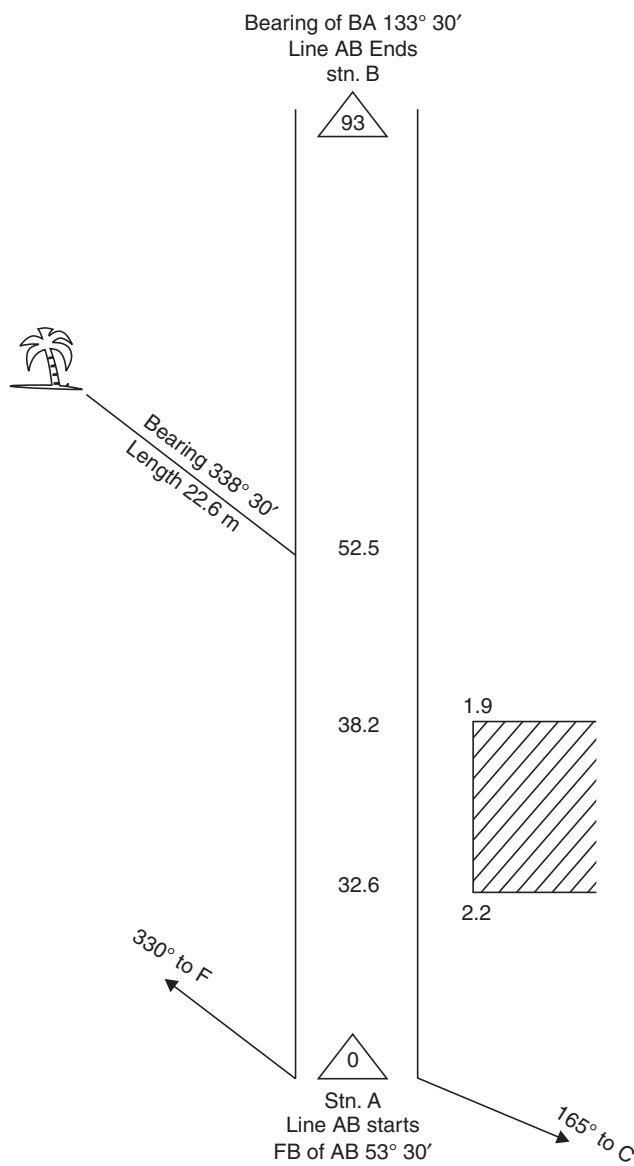


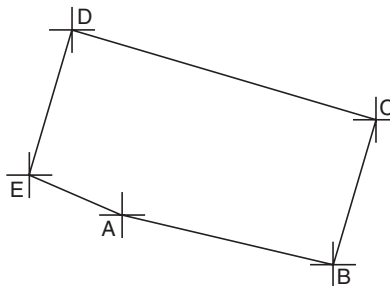
Fig. 13.12

**QUESTIONS**

1. Explain with a neat sketch construction of a prismatic compass.
2. Bring out the differences between prismatic compass and surveyor's compass.
3. Distinguish between
  - (a) Magnetic meridian and true meridian.
  - (b) Whole circle bearing and quadrantal bearing.
  - (c) Declination and dip.
  - (d) Fore bearing and back bearing.
  - (e) Isogonic and agonic lines.
4. What is meant by magnetic declination? List the different types of its variations.
5. What is local attractions? How it is detected in the field?
6. What are the precautions to be taken while taking bearing of a line with a compass.
7. In traversing in anticlockwise direction, the following readings were observed:

Line	AB	BC	CD	DE	EA
FB	105° 15'	20° 00'	316° 30'	187° 15'	122° 45'

Draw a neat sketch of the traverse. Determine the interior angles of the traverse and apply check.



$$\begin{aligned}
 \angle A &= 162^\circ 30' & \angle B &= 94^\circ 45' \\
 \angle C &= 116^\circ 30' & \angle D &= 50^\circ 45' \\
 \angle E &= 115^\circ 30' & \Sigma\theta &= 540^\circ \text{ Checked.} \quad \text{Ans.}
 \end{aligned}$$

8. The following bearings were taken in running a compass traverse:

Line	FB	BB
AB	124° 30'	304° 30'
BC	68° 15'	246° 00'
CD	310° 30'	135° 15'
DA	200° 15'	17° 45'

At what stations do you suspect local attraction? Find the correct bearings of the lines and also compute the included angles.



**Ans.** Stations C and D are affected by local attraction. Correct bearing of lines are as shown below:

<i>Line</i>	<i>FB</i>	<i>BB</i>
AB	124° 30'	304° 30'
BC	68° 15'	248° 15'
CD	312° 45'	132° 45'
DA	197° 45'	17° 45'

$\angle A = 106^\circ 45'$     $\angle B = 123^\circ 45'$     $\angle C = 64^\circ 30'$     $\angle D = 65^\circ$     $\Sigma\theta = 360^\circ$    **Checked.**

## Plane Table Surveying

In this method of surveying a table top, similar to drawing board fitted on to a tripod is the main instrument. A drawing sheet is fixed on to the table top, the observations are made to the objects, distances are scaled down and the objects are plotted in the field itself. Since the plotting is made in the field itself, there is no chance of omitting any necessary measurement in this surveying. However the accuracy achieved in this type of surveying is less. Hence this type of surveying is used for filling up details between the survey stations previously fixed by other methods.

In this chapter, accessories required, working operations and methods of plane table surveying are explained. At the end advantages and limitations of this method are listed.

### 14.1 PLANE TABLE AND ITS ACCESSORIES

The most commonly used plane table is shown in Fig. 14.1. It consists of a well seasoned wooden table top mounted on a tripod. The table top can rotate about vertical axis freely. Whenever necessary table can be clamped in the desired orientation. The table can be levelled by adjusting tripod legs.

Adjusting the tripod

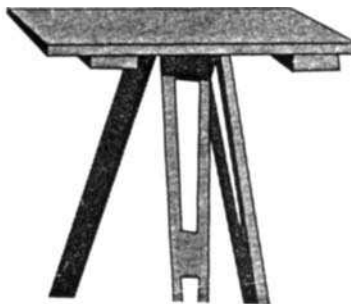


Fig. 14.1. Plane table with stand

The following accessories are required to carry out plane table survey:

1. Alidade
2. Plumbing fork with plumb bob.

3. Spirit level
4. Trough compass
5. Drawing sheets and accessories for drawing.

### 14.1.1 Alidade

It is a straight edge ruler having some form of sighting device. One edge of the ruler is bevelled and is graduated. Always this edge is used for drawing line of sight. Depending on the type of line of sight there are two types of alidade:

(a) Plain alidade

(b) Telescopic alidade

**Plain Alidade:** Figure 14.2 shows a typical plain alidade. A sight vane is provided at each end of the ruler. The vane with narrow slit serves as eye vane and the other with wide slit and having a thin wire at its centre serves as object vane. The two vanes are provided with hinges at the ends of ruler so that when not in use they can be folded on the ruler. Plain alidade is not suitable in surveying hilly areas as the inclination of line of sight in this case is limited.

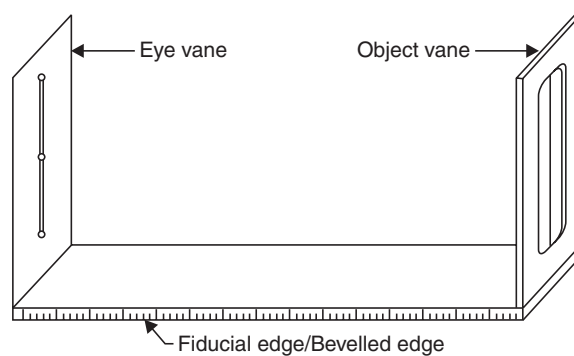


Fig. 14.2. Plane alidade

**Telescopic Alidade:** It consists of a telescope mounted on a column fixed to the ruler [Fig. 14.3]. The line of sight through the telescope is kept parallel to the bevelled edge of the ruler. The telescope is provided with a level tube and vertical graduation arc. If horizontal sight is required bubble in the level tube is kept at the centre. If inclined sights are required vertical graduation helps in noting the inclination of the line of sight. By providing telescope the range and the accuracy of line of sight is increased.

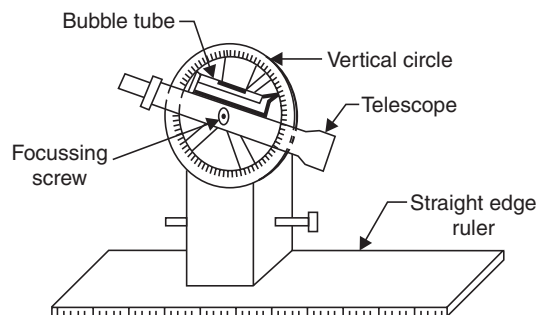


Fig. 14.3. Telescopic alidade

### 14.1.2 Plumbing Fork and Plumb Bob

Figure 14.4 shows a typical plumbing fork with a plum bob. Plumbing fork is a U-shaped metal frame with an upper horizontal arm and a lower inclined arm. The upper arm is provided with a pointer at the end while the lower arm is provided with a hook to suspend plumb bob. When the plumbing fork is kept on the plane table the vertical line (line of plumb bob) passes through the pointed edge of upper arm. The plumb bob helps in transferring the ground point to the drawing sheet and vice versa also.

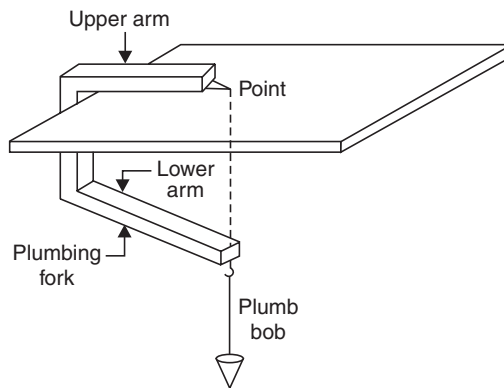


Fig. 14.4. Plumbing fork and plumb bob.

### 14.1.3 Spirit Level

A flat based spirit level is used to level the plane table during surveying (Fig. 14.5). To get perfect level, spirit level should show central position for bubble tube when checked with its positions in any two mutually perpendicular direction.

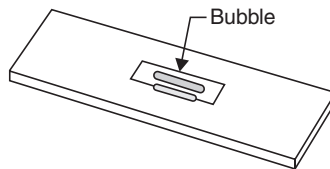


Fig. 14.5. Spirit level

### 14.1.4 Trough Compass

It consists of a 80 to 150 mm long and 30 mm wide box carrying a freely suspended needle at its centre (Ref. Fig. 14.6). At the ends of the needle graduations are marked on the box to indicate zero to five degrees on either side of the centre. The box is provided with glass top to prevent oscillation of the needle by wind. When needle is centred (reading 0-0), the line of needle is parallel to the edge of the box. Hence marking on the edges in this state indicates magnetic north-south direction.

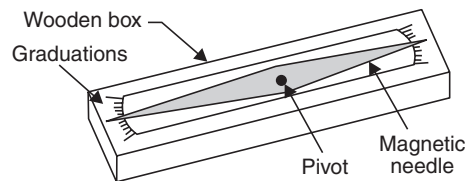


Fig. 14.6. Trough compass

### 14.1.5 Drawing Sheet and Accessories for Drawing

A good quality, seasoned drawing sheet should be used for plane table surveying. The drawing sheet may be rolled when not in use, but should never be folded. For important works fibre glass sheets or paper backed with thin aluminium sheets are used.

Clips clamps, adhesive tapes may be used for fixing drawing sheet to the plane table. Sharp hard pencil, good quality eraser, pencil cutter and sand paper to keep pencil point sharp are other accessories required for the drawing work. If necessary, plastic sheet should be carried to cover the drawing sheet from rain and dust.

## 14.2 WORKING OPERATIONS

---

After fixing the table top to the stand and drawing sheet to the table, the following operations are to be carried out before map making:

1. Centering
2. Levelling
3. Orientation.

### 14.2.1 Centering

Centering is the process of setting the plane table on the point so that its plotted position is exactly over the position on the ground. This is achieved by moving the legs of the tripod and checking the position of the point on the ground and on the paper with the help of plumbing fork and plumb bob.

### 14.2.2 Levelling

The level of the plane table should be ensured in two positions of spirit level which are at right angles to each other. The legs of tripod are moved radially or along the circumference to adjust the plane table and get levelled surface.

### 14.2.3 Orientation

Orientation is the process of setting plane table over a station such that all the lines already plotted are parallel to corresponding lines on the ground. Accuracy of plane table survey mainly depends upon the accuracy of orientation of plane table at each station point. It can be achieved by any one of the following methods:

- (a) using trough compass
- (b) by back sighting
- (c) by solving two point or three point problems.

The first two methods are commonly used while the third method is used occasionally. The third method is explained under the article methods of plane tabling by resection.

(a) *Orientation Using Trough Compass:* When the survey work starts, the plane table is set on first station and the table is oriented by rough judgement such that the plotted position of the area falls in the middle portion of the paper. Then the table is clamped and the north direction is marked on right hand side top corner of drawing sheet. Trough compass is used to identify north direction. This orientation is to be maintained at all subsequent stations. After centering and levelling the table trough compass is kept along the marked north direction and the table is rotated to get freely suspended magnetic needle centred. After achieving it the table is clamped.

This method of orientation is considered rough, since the local attraction to magnetic needle affects the orientation. This method is used as preliminary orientation and finer tuning is made by observing the already plotted points.

(b) *Orientation by Back Sighting:* It is the commonly used method in plane table surveying. After completing surveying from plane table set at A, if table is to be shifted to next station B, a line is drawn from the plotted position of station A towards station B. Then distance AB is measured, scaled down and plotted position of station B is obtained. Then table is shifted to station B, centred, levelled. Then keeping alidade along BA, station A is sighted and the table is clamped. Thus the orientation of the table is achieved by back sighting. Orientation may be checked by observing already plotted objects.

### 14.3 METHODS OF PLANE TABLING

The following four methods are available for carrying out plane table survey:

1. Radiation
2. Intersection
3. Traversing
4. Resection.

The first two methods are employed for locating details while the other two methods are used for locating position of plane table station on drawing sheet.

#### 14.3.1 Radiation

After setting the plane table on a station, say O, it is required to find the plotted position of various objects A, B, C, D ..... . To get these positions, the rays OA, OB, OC ..... are drawn with soft pencil (Ref. Fig. 14.7). Then the distances OA, OB, OC ....., are measured scaled down and the positions of A, B, C ....., are found on the drawing sheets.

This method is suitable for surveying small areas and is convenient if the distances to be measured are small. For larger areas this method has wider scope, if telescopic alidade is used, in which the distances are measured technometrically.

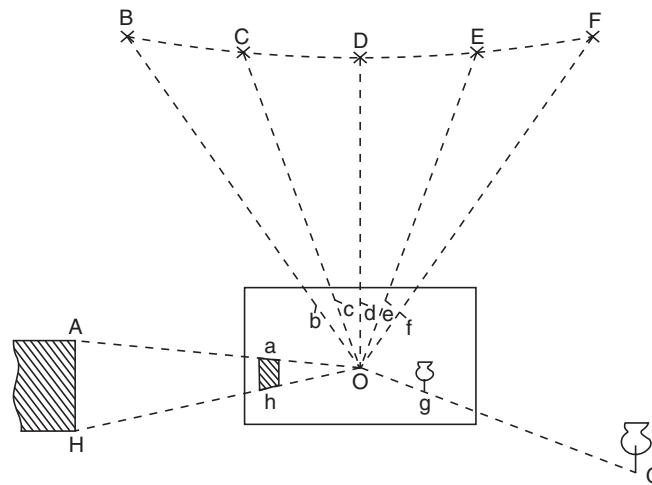


Fig. 14.7. Radiation method of plane tabling

### 14.3.2 Intersection

In this method the plotted position of an object is obtained by plotting rays to the object from two stations. The intersection gives the plotted position. Thus it needs the linear measurements only between the station points and do not need the measurements to the objects. Figure 14.8 shows the method for locating objects A and B from plane table positions  $O_1$  and  $O_2$ .

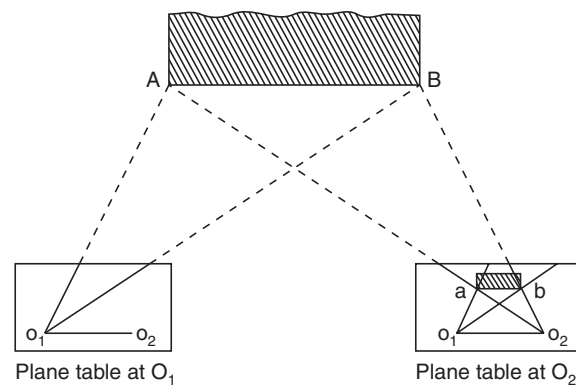


Fig. 14.8. Intersection method of plane tabling

This method is commonly employed for locating:

- (a) details
- (b) the distant and inaccessible points
- (c) the stations which may be used latter.

### 14.3.3 Traversing

This is the method used for locating plane table survey stations. In this method, ray is drawn to next station before shifting the table and distance between the stations measured. The distance is scaled

down and next station is located. After setting the plane table at new station orientation is achieved by back sighting. To ensure additional checks, rays are taken to other stations also, whenever it is possible. Figure 14.9 shows a scheme of plane table survey of closed area. This method can be used for open traverses also.

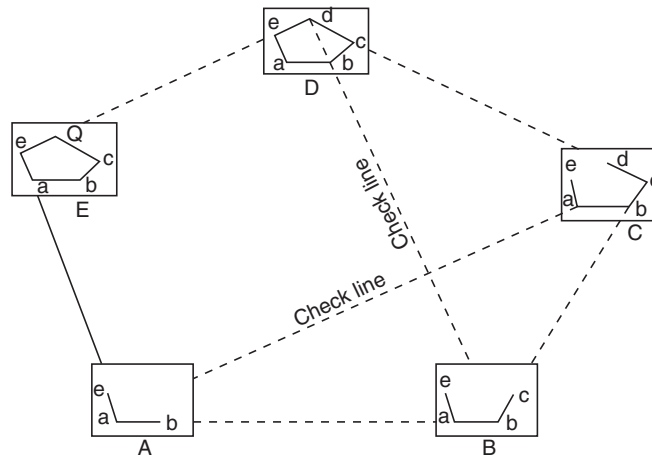


Fig. 14.9. Plane table traversing

#### 14.3.4 Resection

This method is just opposite to the method of intersection. In the method of intersection, the plotted position of stations are known and the plotted position of objects are obtained by intersection. In this method the plotted position of objects are known and the plotted position of station is obtained. If  $a$ ,  $b$  and  $c$  are the plotted positions of objects A, B and C respectively, to locate instrument station P on the paper, the orientation of table is achieved with the help of  $a$ ,  $b$ ,  $c$  and then resectors Aa, Bb, Cc are drawn to get the ' $p$ ', the plotted position of P. Hence in the resection method major work is to ensure suitable orientation by any one of the methods. The following methods are employed in the method of resection:

- (a) by compass
- (b) by back sighting
- (c) by solving two point problem
- (d) by solving three point problem.

- (a) *Resection after Orientation by Compass:* Let  $a$  and  $b$  be the plotted positions of A and B of two well defined points in the field. Keeping the through compass along north direction marked on the drawing sheet table is oriented on station P, the position of which is to be found on paper. The resectors Aa and Bb [Fig. 14.10] are drawn to locate ' $p$ ' the plotted position of station point P.

This method gives satisfactory results, if the area is not influenced by local attractions. It is used for small scale mapping only.



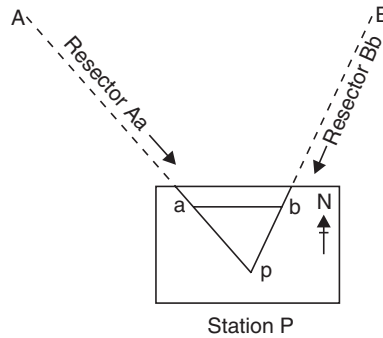


Fig. 14.10. Resection after orientation with compass

(b) *Resection after Orientation by Back Sighting:* Figure 14.11 shows the scheme of resection after orientation by back sighting. From station A, the position of B is plotted as 'b' and ray has been taken to station P as  $ap'$ . Then plane table is set at P and oriented by back sighting A, line AP is not measured but the position of P is obtained on the paper by taking resection Bb.

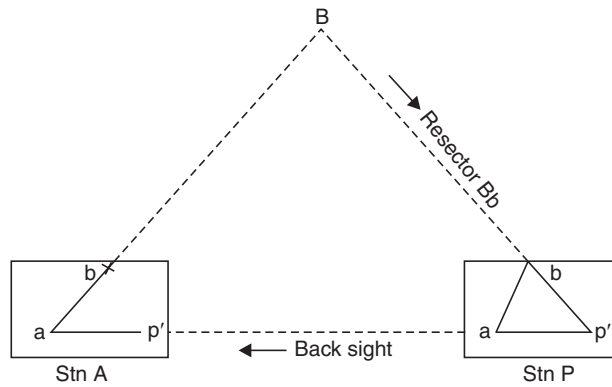


Fig. 14.11. Resection after back sighting

(c) *Resection after Solving Two Point Problem:* The problem of finding plotted position of the station point occupied by the plane table with the help of plotted positions of two well defined points is known as solving two point problem. Figure 14.12 shows the scheme of solving this.

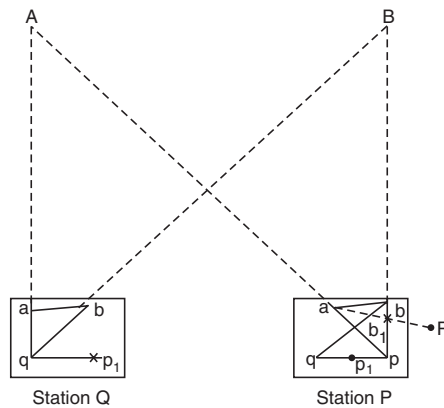


Fig. 14.12. Two-point problem

Let A and B be two well defined points like lightning conductor or spire of church, the plotted positions  $a$  and  $b$  already known. Now the problem is to orient the table at P so that by resection its plotted position  $p$  can be obtained. The following steps may be followed to solve this problems:

- (i) Select a suitable point Q near P such that the angles PAQ and PBQ are not acute.
- (ii) Roughly orient the table at Q and draw the resectors Aa and Bb to get the point 'q'.
- (iii) Draw the ray  $qp$  and locate  $p_1$  with estimated distance QP.
- (iv) Shift the plane table to P and orient the table by back sighting to Q.
- (v) Draw the resector Aa to get 'p'.
- (vi) Draw the ray  $pB$ . Let it intersect line  $bq$  at  $b_1$ .
- (vii) The points  $b$  and  $b_1$  are not coinciding due to the angular error in the orientation of table. The angle  $bab$ , is the angular error in orientation. To correct it,
  - \* Fix a ranging rod at R along  $ab$ ,
  - \* Unclamp the table and rotate it till line  $ab$  sights ranging rod at R. Then clamp the table.
 This gives the correct orientation of the table which was used in plotting the points A and B.
- (viii) The resectors Aa and Bb are drawn to get the correct plotted position 'p' of the station P.
- (d) *Resection after Solving Three Point Problem:* Locating the plotted position of a station point using observations to three well defined points whose plotted positions are known, is called solving three point problem.

Let A, B, C be three well defined objects on the field whose plotted positions  $a$ ,  $b$  and  $c$  are known. Now the problem is to locate plotted position of the station point P. Any one of the following methods can be used.

- (i) Mechanical (Tracing paper) method,
  - (ii) Graphical method, or
  - (iii) Trial and error method (Lehman's method).
- (i) *Mechanical Method:* This method is known as tracing paper method since it needs a tracing paper. The method involved the following steps [Ref. Fig. 14.13.]

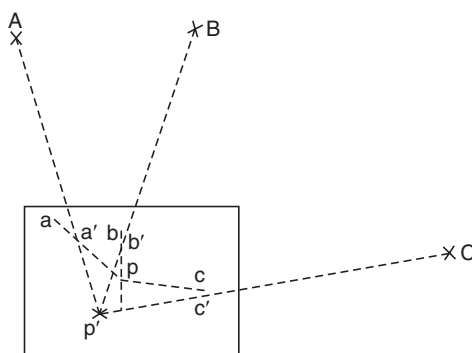


Fig. 14.13

- \* Set the table over station P and by observation approximately orient the table.
- \* Fix the tracing paper on the plane table and select P approximately, say as  $p'$ . From  $p'$ , draw  $p'A$ ,  $p'B$  and  $p'C$ . These lines may not pass through the plotted positions  $a$ ,  $b$  and  $c$  since the orientation is not exact.
- \* Loosen the tracing paper and rotate it so that the rays pass through respective points  $a$ ,  $b$  and  $c$ . Now prick the point  $p'$  to get the plotted position ' $p$ ' of the station P.
- \* Keep the alidade along  $pa$  and sight A. Then clamp the table. This is correct orientation. Check the orientation by observing along  $pb$  and  $pc$ .

(ii) *Graphical Method:* The following two graphical methods are available to solve three point problem:

- \* Bessel's solution
- \* Method of perpendiculars.

**Bessels Solution:** It involves the following steps:

1. Keep the bevelled edge of alidade along  $ba$  and sight object at A. Clamp the table and draw  $bc'$  along the line  $bc$  [Fig. 14.14 (a)].
2. Keep bevelled edge of alidade along  $ab$ , unclamp the table and sight B. Clamp the table. Draw line  $ac$  intersecting  $bc'$  at  $d$  [Fig. 14.14(b)].
3. Keep the alidade along  $dc$  and bisect C. Clamp the table [Fig. 14.14(c)]. This gives the correct orientation.
4. Draw resectors to get ' $p$ '.

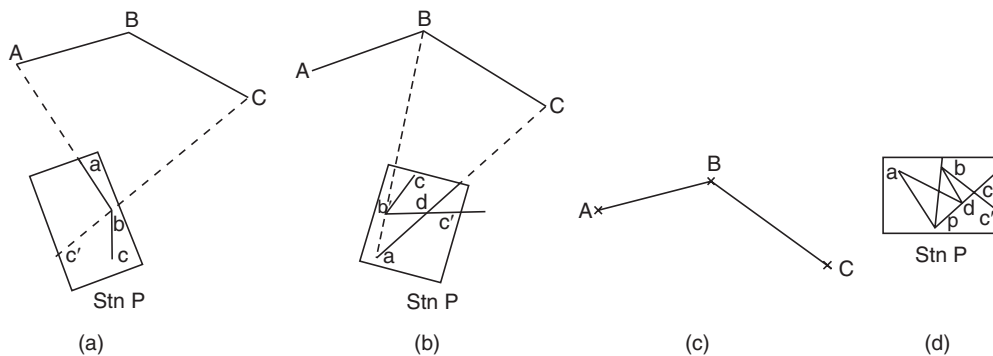


Fig. 14.14. Graphical solution (Bessel's method)

### Method of Perpendiculars

This is another graphical method. It involves the following steps [Ref. Fig. 14.15].

1. Draw line  $ae$  perpendicular to  $ab$ . Keep alidade along  $ea$  and turn the table till A is sighted. Clamp the table and draw the ray  $Bb$  to intersect the ray  $Aac$  at  $e$  [Fig. 14.15(a)].
2. Draw  $cf$  perpendicular to  $bc$  and clamp the table when  $fcC$  are in a line. Draw  $Bb$  to intersect  $Ccf$  at  $F$  [Fig. 14.15(b)].

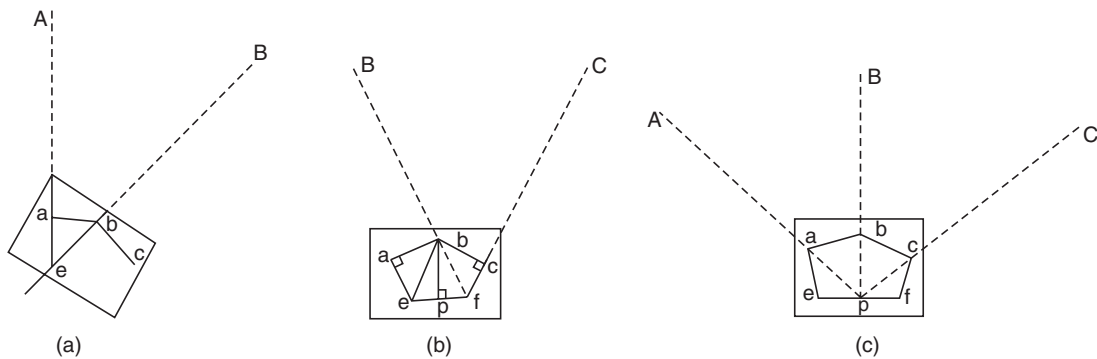


Fig. 14.15. Method of perpendiculars of solve three point problem

3. Join  $cf$  drop  $bp$  perpendicular to  $ef$  to get the plotted position ' $p$ '.
4. Orient the table such that  $pbB$  are in a line. Clamp the table to place it in correct orientation. Resections  $Aa$  and  $Cc$  may be used to check the orientation.

**Trial and Error Method**

This method is also known as '*triangle of error method*' and '*Lehman's Method*'. It involves the following steps:

1. Set the table over point  $P$  and orient the table approximately, just by observation.
2. Draw the rays  $aA, bB$  and  $cC$  [Fig. 14.16]. If the orientation was perfect, the three rays would have intersected at a single point, i.e. at point ' $p$ '. Otherwise a triangle of error is formed.
3. To eliminate the triangle of error an approximate position, ray  $p'$ , is selected near the triangle of error. Then keeping alidade along  $p'a$  object  $A$  is sighted and the table is clamped. Draw the resectors  $cC$  and  $bB$  to check the orientation.
4. Above step is repeated till triangle of error is eliminated.

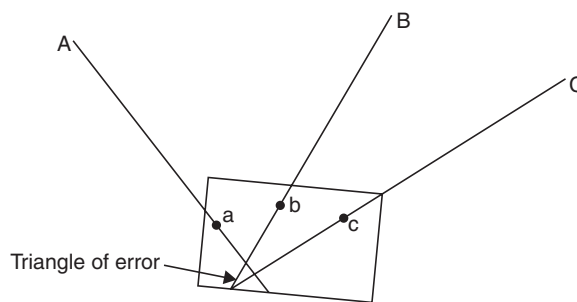


Fig. 14.16

Lehman presented the following guidelines to select ' $p'$ ' so that triangle of error is eliminated quickly.

**Rule 1:** The distance of point sought ' $p$ ' is in the same proportion from the corresponding rays as the distance of those from the plane table station.

**Rule 2:** The point sought 'p' is on the same side of all the three resectors.

Defining the triangle ABC on the field as great triangle and the circle passing through them as great circle, from the above two rules of Lehman, the following sub-rules may be drawn [Ref. Fig. 14.17].

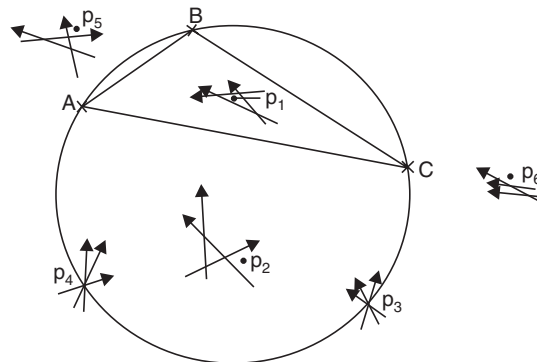


Fig. 14.17

- \* If 'P' lies within the great triangle, the point 'p' is within the triangle of error ( $p_1$  in the Fig. 14.17).
- \* If the plane table station P lies outside the great triangle the point sought 'p' is outside the triangle of errors ( $p_2$ ).
- \* If the 'P' is on the great circle, the correct solution is impossible ( $p_3$  and  $p_4$ ).
- \* If 'P' is outside the great circle, 'p' is nearer to the intersection of rays to the nearest two points ( $P_5$ ).
- \* If point P is outside the great circle and the two rays drawn are parallel to each other the point sought is outside the parallel lines and on the same side of the three rays ( $P_6$ ).

## 14.4 ERRORS IN PLANE TABLE SURVEYING

The errors may be grouped into the instrumental and personal errors.

### 14.4.1 Instrumental Errors

1. The surface of plane table not perfectly plane.
2. Bevelled edge of alidade not straight.
3. Sight vanes of alidade not perfectly perpendicular to the base.
4. Plane table clamp being loose.
5. Magnetic compass being sluggish.
6. Drawing sheet being of poor quality.

#### 14.4.2 Personal Errors

1. Centering errors
2. Levelling errors
3. Orientation errors
4. Sighting errors
5. Errors in measurement
6. Plotting errors
7. Errors due to instability of tripod.

### 14.5 ADVANTAGES AND LIMITATIONS OF PLANE TABLE SURVEY

#### Advantages are

1. Possibility of omitting measurement is eliminated.
2. The surveyor can compare the plotted work in the field then and there only.
3. Irregular objects are plotted more accurately, since they are seen while plotting.
4. Booking errors are eliminated.
5. Local attractions do not influence the plotting.
6. No great skill is required to produce satisfactory maps.
7. Method is fast.
8. No costly instruments are required.

#### Limitations are

1. Survey cannot be conducted in wet weather and rainy days.
2. Plane table is cumbersome and heavy to carry.
3. It needs many accessories.
4. It is less accurate.
5. Reproduction of map to different scale is difficult.

### QUESTIONS

1. What are the accessories required for plane table survey?
2. Briefly explains setting and orienting plane table at first station.
3. Explain any two methods of orienting plane table in subsequent stations.
4. Describe any two methods of drawing details in a plane table survey map.
5. How do you find the distance between two inaccessible points by plane table surveying? Explain.

6. Explain the following terms used in plane table surveying:
  - (i) radiation
  - (ii) intersection
  - (iii) resection.
7. Explain the two point problem and its solution.
8. State three point problem in plane table surveying and explain any one method to solve it.
9. List the various possible errors in plane table surveying.
10. What are the advantages and limitations of plane table surveying?

## Level and Levelling

Elevation measurements involve measurements in vertical plane. It is also known as levelling. It may be *defined as the art of determining the elevations of given points above or below a datum line or establishing given points of required heights above or below the datum line.*

### 15.1 OBJECT AND USES OF LEVELLING

As stated in the definition of levelling, the object is

- (i) to determine the elevations of given points with respect to a datum
- (ii) to establish the points of required height above or below the datum line.

Uses of levelling are

- (i) to determine or to set the plinth level of a building.
- (ii) to decide or set the road, railway, canal or sewage line alignment.
- (iii) to determine or to set various levels of dams, towers, etc.
- (iv) to determine the capacity of a reservoir.

### 15.2 TERMS USED IN LEVELLING

Before studying the art of levelling, it is necessary to clearly understand the following terms used in levelling:

- 1. Level Surface:** A surface parallel to the mean spheroid of the earth is called a level surface and the line drawn on the level surface is known as a level line. Hence all points lying on a level surface are equidistant from the centre of the earth. Figure 15.1 shows a typical level surface.



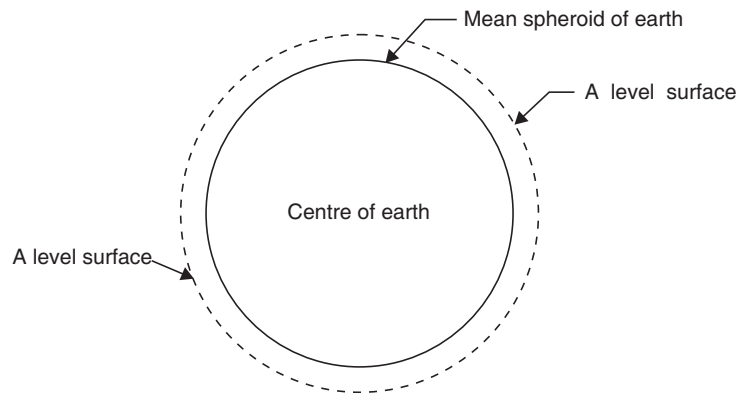


Fig. 15.1. A level surface

- 2. Horizontal Surface:** A surface tangential to level surface at a given point is called horizontal surface at that point. Hence a horizontal line is at right angles to the plumb line at that point [Ref. Fig. 15.2].

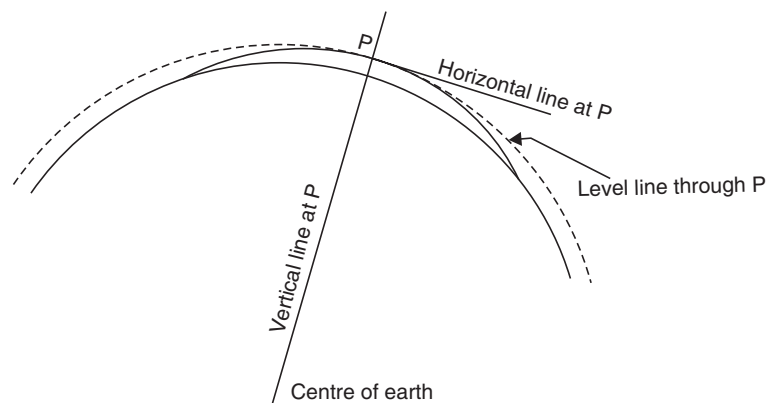


Fig. 15.2. Vertical and horizontal lines

- 3. Vertical Line:** A vertical line at a point is the line connecting the point to the centre of the earth. It is the plumb line at that point. Vertical and horizontal lines at a point are at right angles to each other [Fig. 15.2].
- 4. Datum:** The level of a point or the surface with respect to which levels of other points or planes are calculated, is called a datum or datum surface.
- 5. Mean Sea Level (MSL):** MSL is the average height of the sea for all stages of the tides. At any particular place MSL is established by finding the mean sea level (free of tides) after averaging tide heights over a long period of at least 19 years. In India MSL used is that established at Karachi, presently, in Pakistan. In all important surveys this is used as datum.
- 6. Reduced Levels (RL):** The level of a point taken as height above the datum surface is known as RL of that point.

**7. Benchmarks:** A benchmark is a relatively permanent reference point, the elevation of which is known (assumed or known w.r.t. MSL). It is used as a starting point for levelling or as a point upon which to close for a check. The following are the different types of benchmarks used in surveying:

- (a) GTS benchmarks (b) Permanent benchmarks  
(c) Arbitrary benchmarks and (d) Temporary benchmarks.

(a) **GTS Benchmark:** The long form of GTS benchmark is Great Trigonometrical Survey benchmark. These benchmarks are established by national agency. In India, the department of Survey of India is entrusted with such works. GTS benchmarks are established all over the country with highest precision survey, the datum being mean sea level. A bronze plate provided on the top of a concrete pedestal with elevation engraved on it serves as benchmark. It is well protected with masonry structure built around it so that its position is not disturbed by animals or by any unauthorised person. The position of GTS benchmarks are shown in the topo sheets published.

(b) **Permanent Benchmark:** These are the benchmarks established by state government agencies like PWD. They are established with reference to GTS benchmarks. They are usually on the corner of plinth of public buildings.

(c) **Arbitrary Benchmark:** In many engineering projects the difference in elevations of neighbouring points is more important than their reduced level with respect to mean sea level. In such cases a relatively permanent point, like plinth of a building or corner of a culvert, are taken as benchmarks, their level assumed arbitrarily such as 100.0 m, 300.0 m, etc.

(d) **Temporary Benchmark:** This type of benchmark is established at the end of the day's work, so that the next day work may be continued from that point. Such point should be on a permanent object so that next day it is easily identified.

### 15.3 LEVELLING INSTRUMENTS

A level is an instrument giving horizontal line of sight and magnifying the reading at a far away distance. It consists of the following parts:

- (i) A telescope to provide a line of sight  
(ii) A level tube to make the line of sight horizontal and  
(iii) A levelling head to level the instrument.

The following types of levels are available:

- (i) Dumpy level (ii) Wye (or, Y) level  
(iii) Cooke's reversible level (iv) Cushing's level  
(v) Tilting level and (vi) Auto level.

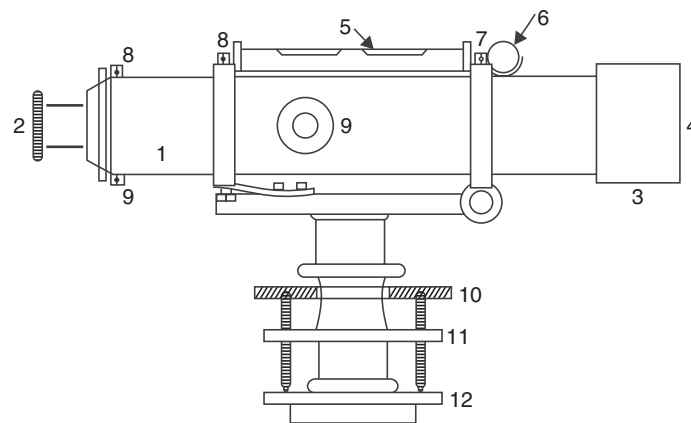
#### 15.3.1 Dumpy Level

It is a short and stout instrument with telescope tube rigidly connected to the vertical spindle. Hence the level tube cannot move in vertical plane. It cannot be removed from its support. Hence it is named as

dummy level. The telescope rotates in horizontal plane in the socket of the levelling head. A bubble tube is attached to the top of the telescope. Figure 15.3 shows a typical dummy level. Plate 15.1 shows its photograph.



Plate 15.1 Dummy level



- |                             |                                     |
|-----------------------------|-------------------------------------|
| 1. Telescope                | 7. Bubble tube adjusting screws     |
| 2. Eyepiece                 | 8. Diaphragm adjusting screws       |
| 3. Shade                    | 9. Focusing screws                  |
| 4. Objective end            | 10. Foot screws                     |
| 5. Longitudinal bubble tube | 11. Upper parallel plate (tribrach) |
| 6. Transverse bubble tube   | 12. Foot plate (Trivet stage)       |

Fig. 15.3. Dummy level

Telescope is a tube with object glass and eyepiece. Object glass can be adjusted using the focussing screw before sighting the graduated staff held on the object. Eyepiece can be adjusted by rotating it to see that parallel is removed and cross hairs appears distinctly. Eyepiece once adjusted needs no change as long as the same person takes the readings.

Level tube is a glass tube with slightly curved shape provided over the level tube. The tube is filled with ether or alcohol leaving a little air gap, which takes the shape of a bubble. The air bubble is always at the highest point. The level tube is fixed with its axis parallel to telescope tube, so that when bubble is centred, the telescope is horizontal. The tube is graduated on either side of its centre to estimate how much the bubble is out of centre. The glass tube is placed inside a brass tube which is open from top and on lower side it is fixed to telescope tube by means of capston headed nuts. The bubble tube is adjusted with these nuts, if it is out of order.

Levelling head consists of two parallel plates with three foot screws. The upper plate is known as tribrach plate and the lower one as the trivet. The lower plate can be screwed on to the tripod stand. By adjusting the screws the instrument can be levelled to get perfect horizontal line of sight.

Dumpy level is to be fitted to a tripod stand to use it in the field. The tripod stand consists of three legs connected to a head to which the lower plate of level can be fitted. The lower side of the legs are provided with metal shoes to get good grip with ground. Plate 15.2 shows typical level stands.



Plate 15.2 Levelling stands (adjustable and non-adjustable)

### 15.3.2 Wye or Y-Level

In this type of level, the telescope is supported in two Y-shaped supports and can be fixed with the help of curved clips. Clips can be opened and telescope can be reversed end to end and fitted. The advantage of this level is some of the errors eliminated, if the readings are taken in both the direction of telescope.

### 15.3.3 Cooke's Reversible Level

In this instrument the telescope is supported by two rigid sockets into which telescope can be introduced from either end and then screwed. For taking the readings in the reversed position of telescope, the screw is slackened and then the telescope is taken out and reversed end for end. Thus it combines the rigidity of dumpy level and reversibility of Y-level.

### 15.3.4 Cushings Level

In this reversing of telescope end for end is achieved by interchanging the eyepiece and the objective piece since both collars are exactly the same.

### 15.3.5 Tilting Level

In this, telescope can be tilted through about four degrees with the help of a tilting screw. Hence bubble can be easily centered. But it needs centering of the bubble before taking every reading. Hence it is useful, if at every setting of the instrument number of readings to be taken are few.

### 15.3.6 Auto Level

The auto-level or the automatic-level is a self aligning level. Within a certain range of tilt automatic levelling is achieved by an inclination compensating device. The operational comfort, high speed and precision are the advantages of this instrument.

## 15.4 LEVELLING STAFF

Along with a level, a levelling staff is also required for levelling. The levelling staff is a rectangular rod having graduations. The staff is provided with a metal shoes at its bottom to resist wear and tear. The foot of the shoe represents zero reading. Levelling staff may be divided into two groups:

(i) Self reading staff

(ii) Target staff.

(i) **Self reading staff:** This staff reading is directly read by the instrument man through telescope. In a metric system staff, one metre length is divided into 200 subdivisions, each of uniform thickness of 5 mm. All divisions are marked with black in a white background. Metres and decimetres are written in red colour [Fig 15.4 (a)]. The following three types of self reading staffs are available:

(a) *Solid staff:* It is a single piece of 3 m.

(b) *Folding staff:* A staff of two pieces each of 2 m which can be folded one over the other.

(c) *Telescopic staff:* A staff of 3 pieces with upper one solid and lower two hollow. The upper part can slide into the central one and the central part can go into the lower part. Each length can be pulled up and held in position by means of brass spring. The total length may be 4 m or 5 m [Fig. 15.4 (b)].

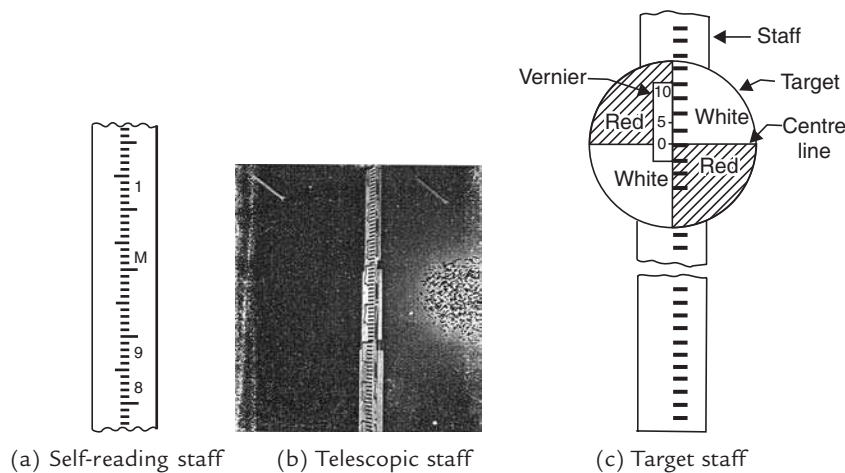


Fig. 15.4

(ii) **Target staff:** If the sighting distance is more, instrument man finds it difficult to read self reading staff. In such case a target staff shown in [Fig. 15.4 (c)] may be used. Target staff is similar to self reading staff, but provided with a movable target. Target is a circular or oval shape, painted red and white in alternate quadrant. It is fitted with a vernier at the centre.

The instrument man directs the person holding target staff to move the target, till its centre is in the horizontal line of sight. Then target man reads the target and is recorded.

## 15.5 METHODS OF LEVELLING

The following methods are used to determine the difference in elevation of various points:

- (i) Barometric levelling
- (ii) Hypsometric levelling
- (iii) Direct levelling and
- (iv) Indirect levelling.

### 15.5.1 Barometric Levelling

This method depends on the principle that atmospheric pressure depends upon the elevation of place. Barometer is used to measure the atmospheric pressure and hence elevation is computed. However it is

not accurate method since the atmospheric pressure depends upon season and temperature also. It may be used in exploratory surveys.

### 15.5.2 Hypsometric Levelling

This is based on the principle that boiling point of water decreases with the elevation of the place. Hence the elevation difference between two points may be found by noting the difference in boiling point of water in the two places. This method is also useful only for exploratory survey.

### 15.5.3 Direct Levelling

It is common form of levelling in all engineering projects. In this method horizontal sight is taken on a graduated staff and the difference in the elevation of line of sight and ground at which staff is held are found. Knowing the height of line of sight from the instrument station the difference in the elevations of instrument station and the ground on which staff is held can be found. This method is thoroughly explained in next article.

### 15.5.4 Indirect Methods

In this method instruments are used to measure the vertical angles. Distance between the instrument and staff is measured by various methods. Then using trigonometric relations, the difference in elevation can be computed. This is considered beyond the scope of this book. One can find details of such methods in books on surveying and levelling.

## 15.6 TERMS USED IN DIRECT METHOD OF LEVELLING

The following terms are used in direct method of levelling:

- (i) **Plane of Collimation:** It is the reduced level of plane of sight with respect to the datum selected. It is also known as '**height of instrument**'. It should not be confused with the height of telescope from the ground where the instrument is set.
- (ii) **Back Sight (BS):** It is the sight taken on a level staff held on the point of known elevation with an intension of determining the plane of collimation. It is always the first reading after the instrument is set in a place. It is also known as plus sight, since this reading is to be added to RL of the point (Benchmark or change point) to get plane of collimation.
- (iii) **Intermediate Sight (IS):** Sights taken on staff after back sight (first sight) and before the last sight (fore sight) are known as intermediate sights. The intension of taking these readings is to find the reduced levels of the points where staff is held. These sights are known as 'minus sights' since the IS reading is to be subtracted from plane of collimation to get RL of the point where staff is held.
- (iv) **Fore Sight (FS):** This is the last reading taken from the instrument station before shifting it or just before ending the work. This is also a minus sight.
- (v) **Change Point (CP):** This is also known as turning point (TP). This is a point on which both fore sights and back sights are taken. After taking fore sight on this point instrument is set at some other convenient point and back sight is taken on the staff held at the same point. The

two readings help in establishing the new plane of collimation with respect to the earlier datum. Since there is time gap between taking the two sights on the change point, it is advisable to select change point on a well defined point.

## 15.7 TEMPORARY ADJUSTMENTS OF A LEVEL

The adjustments to be made at every setting of the instrument are called temporary adjustments. The following three adjustments are required for the instrument whenever set over a new point before taking a reading:

- (i) Setting
- (ii) Levelling and
- (iii) Focussing.

### 15.7.1 Setting

Tripod stand is set on the ground firmly so that its top is at a convenient height. Then the level is fixed on its top. By turning tripod legs radially or circumferentially, the instrument is approximately levelled. Some instruments are provided with a less sensitive circular bubble on tribrach for this purpose.

### 15.7.2 Levelling

The procedure of accurate levelling with three levelling screw is as given below:

- (i) Loosen the clamp and turn the telescope until the bubble axis is parallel to the line joining any two screws [Ref. Fig. 15.5 (a)].

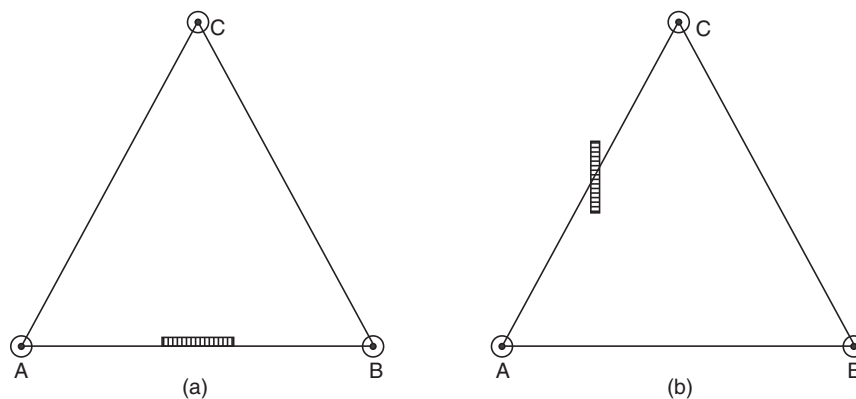


Fig. 15.5

- (ii) Turn the two screws inward or outward equally and simultaneously till bubble is centred.
- (iii) Turn the telescope by  $90^\circ$  so that it lies over the third screw [Fig. 15.4 (b)] and level the instrument by operating the third screw.
- (iv) Turn back the telescope to its original position [Fig. 15.5 (a)] and check the bubble. Repeat steps (ii) to (iv) till bubble is centred for both positions of the telescope.
- (v) Rotate the instrument by  $180^\circ$ . Check the levelling.

### 15.7.3 Focussing

Focussing is necessary to eliminate parallax while taking reading on the staff. The following two steps are required in focussing:

- (i) **Focussing the eyepiece:** For this, hold a sheet of white paper in front of telescope and rotate eyepiece in or out till the cross hairs are seen sharp and distinct.
- (ii) **Focussing the objective:** For this telescope is directed towards the staff and the focussing screw is turned till the reading appears clear and sharp.

## 15.8 TYPES OF DIRECT LEVELLING

The following are the different types of direct levelling:

- (i) Simple levelling
- (ii) Differential levelling
- (iii) Fly levelling
- (iv) Profile levelling
- (v) Cross sectioning and
- (vi) Reciprocal levelling.

### 15.8.1 Simple Levelling

It is the method used for finding difference between the levels of two nearby points. Figure 15.6 shows one such case in which level of A is assumed, say 200.00 m. RL of B is required.

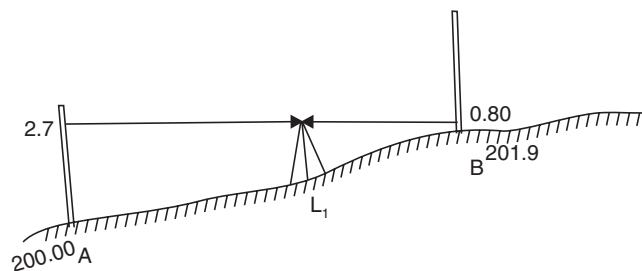


Fig. 15.6

$$\text{RL of A} = 200.00 \text{ m}$$

$$\text{Back sight on A} = 2.7 \text{ m.}$$

$$\begin{aligned} \therefore \text{Plane of collimation for setting at station} &= 200 + 2.7 \\ &= 202.7 \text{ m} \end{aligned}$$

$$\text{Fore sight on B} = 0.80 \text{ m}$$

$$\begin{aligned} \therefore \text{RL of B} &= 202.7 - 0.80 \\ &= 201.9 \text{ m} \end{aligned}$$

It may be noted that the instrument station  $L_1$  need not be along the line AB (in plan) and RL of  $L_1$  do not appear in the calculations.

### 15.8.2 Differential Levelling

If the distance between two points A and B is large, it may not be possible to take the readings on A and B from a single setting.



In such situation differential levelling is used. In differential levelling the instrument is set at more than one position, each shifting facilitated by a change point. Figure 15.7 shows a scheme of such setting.

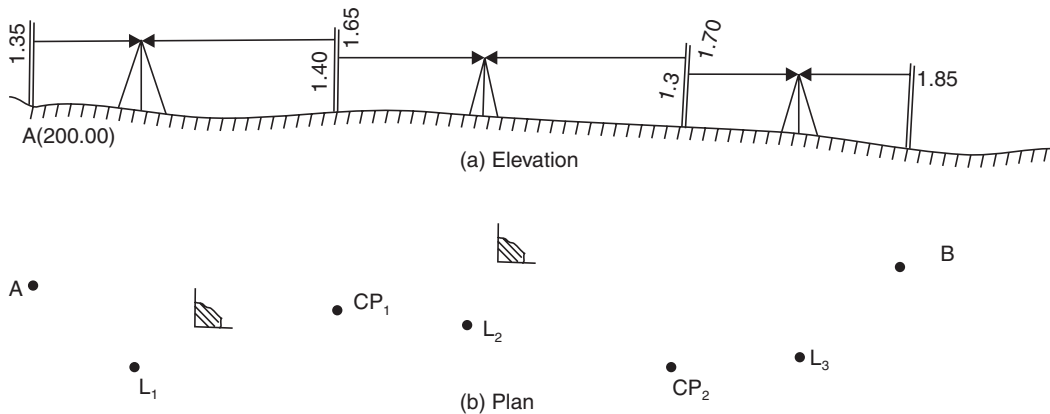


Fig. 15.7

RL of A is 200.00 m. Instrument is set up at  $L_1$  and back sight on A is 1.35 m. The fore sight on change point  $CP_1$  is 1.65 m. Then instrument is shifted to  $L_2$  and back sight on  $CP_1$  is 1.40 m. Fore sight on  $CP_2$  is 1.70 m. After this instrument is shifted to  $L_3$  and back sight on  $CP_2$  is 1.30 m. The work ended with a fore sight of 1.85 m on B. The RL of B is to be found.

$$\text{RL of A} = 200.00 \text{ m}$$

$$\text{Back sight on A} = 1.35 \text{ m}$$

$$\therefore \text{Plane of collimation at } L_1 = 200 + 1.35 = 201.35 \text{ m}$$

$$\text{Fore sight on } CP_1 = 1.65 \text{ m}$$

$$\therefore \text{RL of } CP_1 = 201.35 - 1.65 = 199.70 \text{ m}$$

$$\text{Back sight to } CP_1 \text{ from } L_2 = 1.40$$

$$\therefore \text{Plane of collimation at } L_2 = 199.70 + 1.40 = 201.10 \text{ m}$$

$$\text{Fore sight to } CP_2 = 1.70 \text{ m}$$

$$\therefore \text{RL of } CP_2 = 201.10 - 1.70 = 199.40 \text{ m}$$

$$\text{Back sight to } CP_2 \text{ from } L_3 = 1.30 \text{ m}$$

$$\therefore \text{Plane of collimation at } L_3 = 199.40 + 1.30 = 200.70 \text{ m}$$

$$\text{Fore sight to B} = 1.85 \text{ m}$$

$$\therefore \text{RL of B} = 200.70 - 1.85 = \mathbf{198.85 \text{ m}} \quad \text{Ans.}$$

If there are intermediate sight to the points  $E_1$  and  $E_2$ , the RL of those points may be obtained by subtracting readings for  $E_1$  and  $E_2$  from the corresponding plane of collimations.

### Booking and Reducing the Levels

The booking of readings and reducing the levels can be carried out systematically in the tabular form. There are two such methods:

- (i) Plane of collimation method                      (ii) Rise and fall method.

For the above problem, with intermediate sights to  $E_1 = 0.80 \text{ m}$  and  $E_2 = 0.70 \text{ m}$  is illustrated below by the both methods.

**Table 15.1.** Booking and reducing levels by plane of collimation method

Station	BS	Reading IS	FS	Plane of Collimation	RL	Remarks
A	1.35			201.35	200.00	Benchmark
E <sub>1</sub>		0.80			200.55	Plinth of building
CP <sub>1</sub>	1.40		1.65	201.10	199.70	CP <sub>1</sub>
E <sub>2</sub>		0.70			200.40	Plinth of building
CP <sub>2</sub>	1.30		1.70	200.70	199.40	CP <sub>2</sub>
B			1.85		198.85	B
Check $\Sigma BS = 4.05$		$\Sigma FS = 5.20$		Diff in RL of A and B		
$\Sigma BS - \Sigma FS = -1.15$ (Fall)					$= 198.85 - 200.00 = -1.15$	

In this method note the following:

1. Plane of collimation for first setting  
= RL of BM + BS
2. Subtract IS from plane of collimation to get RL of intermediate station and subtract FS from plane of collimation to get RL of change point.
3. Add back sight to RL of change point to get new plane of collimation.
4. Check:  $\Sigma BS - \Sigma FS = \text{RL of Last point} - \text{RL of first point}$ .

If it is -ve, it is fall and if +ve it is rise.

**Table 15.2.** Booking and reducing level by rise and fall method

Station	BS	IS	FS	Rise	Fall	RL	Remarks
A	1.35					200.00	Benchmark
		0.80		0.55		200.55	E <sub>1</sub>
	1.40		1.65		0.85	199.70	CP <sub>1</sub>
		0.70		0.70		200.40	E <sub>2</sub>
	1.30		1.70		1.00	199.40	CP <sub>2</sub>
			1.85		0.55	198.85	B
$\Sigma BS = 4.05$		$\Sigma FS = 5.20$		$\Sigma Rise = 1.25$	$\Sigma Fall = 2.40$		
Check: $\Sigma BS - \Sigma FS = -1.15$		$\Sigma Rise - \Sigma Fall = -1.15$		RL of last point - RL of first point = -1.15			

Note the following:

1. From A to  $E_1$ , difference =  $1.35 - 0.80 = 0.55$ , rise
2. From  $E_1$  to  $CP_1$ , difference =  $0.80 - 1.65 = -0.85$ , fall
3. From  $CP_1$  to  $E_2$ , difference =  $1.40 - 0.70 = 0.70$ , rise
4. From  $E_2$  to  $CP_2$ , difference =  $0.70 - 1.70 = -1.00$ , fall
5. From  $CP_2$  to B, difference =  $1.30 - 1.85 = -0.55$ , fall.

### 15.8.3 Fly Levelling

If the work site is away from the benchmark, surveyor starts the work with a back sight on the benchmark by setting instrument at a convenient point. Then he proceeds towards the site by taking fore sights and back sights on a number of change points till he establishes a temporary benchmark in the site. Rest of the levelling work is carried out in the site. At the end of the work again levelling is carried out by taking a set of convenient change points till the bench work is reached. This type of levelling in which only back sight and fore sights are taken, is called fly levelling, the purpose being to connect a benchmark with a temporary benchmark or vice versa. Thus the difference between fly levelling and differential levelling is only in the purpose of levelling.

### 15.8.4 Profile Levelling

This type of levelling is known as longitudinal sectioning. In high way, railway, canal or sewage line projects profile of the ground along selected routes are required. In such cases, along the route, at regular interval readings are taken and RL of various points are found. Then the section of the route is drawn to get the profile. Figure 15.8 (a) shows the plan view of the scheme of levelling and Fig. 15.8 (b) shows the profile of the route. For drawing profile of the route, vertical scale is usually larger compared to scale for horizontal distances. It gives clear picture of the profile of the route.

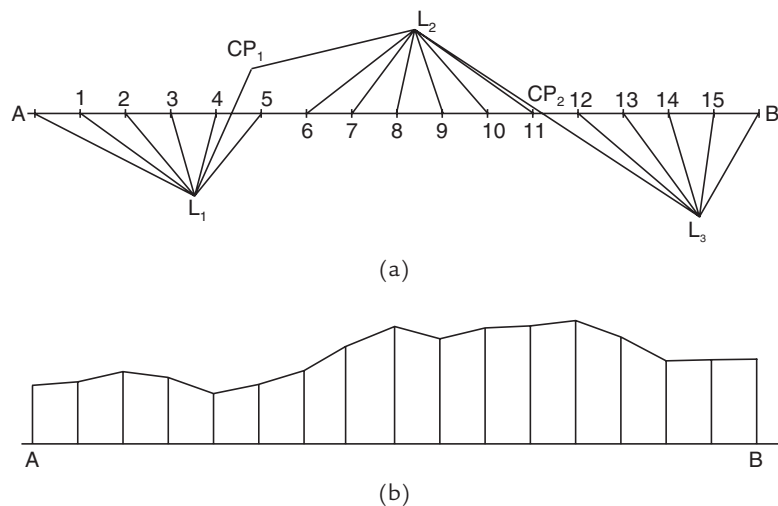


Fig. 15.8

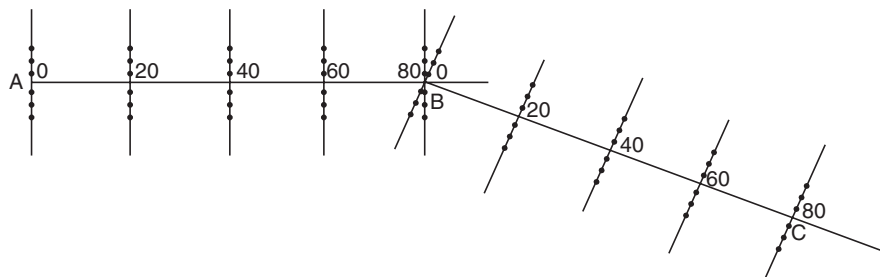
The typical page of field book for this work will be having an additional column to note distances as shown in Table 15.3.

**Table 15.3.** Page of level book for profile levelling

Station	Distance	BS	IS	FS	Plane of Collimation	RL	Remark

**15.8.5 Cross-Sectioning**

In many engineering projects, not only longitudinal profile but also the profile of cross-sections at regular intervals are required. These profiles help in calculating the earth works involved in the projects. Figure 15.9 shows the scheme of such work in which longitudinal profile is found by taking readings at 20 m interval along chain lines AB, BC and readings are taken at an interval of 3 m on either side. The distances on the cross-sections are treated as left or right of the lines as they are found while facing the forward station of survey. The cross-sectional length depends upon the nature of the project.



**Fig. 15.9**

Table 15.4 shows a page of level book required for this type of levelling.

**Table 15.4.** A typical page book for cross-section levelling

Station	Distance in m			Readings			Plane of Collimation	RL	Remarks
	L	C	R	BS	IS	FS			
BM		0							
L <sub>1</sub>	3								
L <sub>2</sub>	6								
L <sub>3</sub>	9								
R <sub>1</sub>			3						
R <sub>2</sub>			6						

R <sub>3</sub>		20	9						
L <sub>1</sub>	3								
L <sub>2</sub>	6								
L <sub>3</sub>	9								
R <sub>1</sub>			3						
R <sub>2</sub>			6						
R <sub>3</sub>			9						
Checked.									

### 15.8.6 Reciprocal Levelling

In levelling, it is better to keep distance of back sight and fore sight equal. By doing so the following errors are eliminated:

- (i) Error due to non-parallelism of line of collimation and axis of bubble tube.
- (ii) Errors due to curvature and refraction.

But in levelling across obstacles like river and ravine, it is not possible to maintain equal distances for fore sight and back sight. In such situations reciprocal levelling as described below is used:

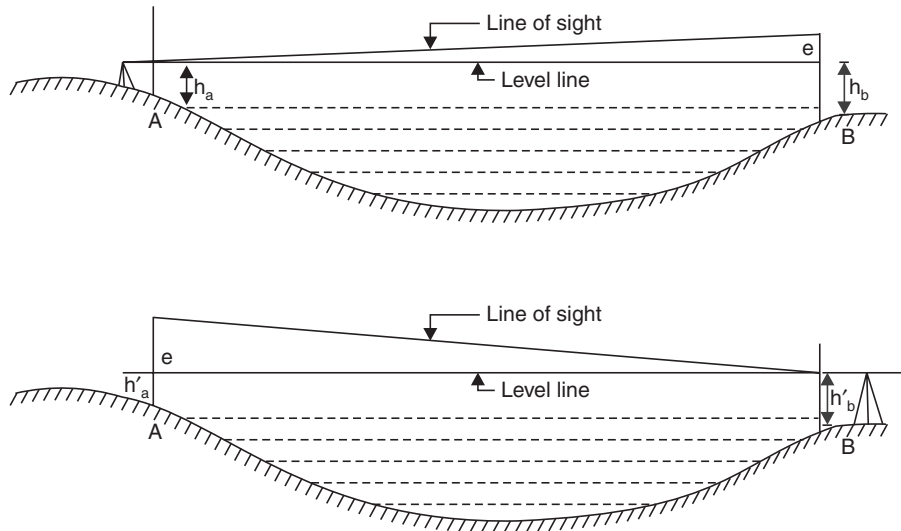


Fig. 15.10

(i) Referring to Fig. 15.10 (a).

Since A is very close, error in reading at A is negligible. Hence  $h_a$  is correct reading.

Let error in  $h_b$  be 'e',

Then correct reading at B =  $h_b - e$

$\therefore$  Difference in elevations =  $H = h_a - (h_b - e)$  ... (i)

(ii) Referring to Fig. 15.10 (b), since B is very close to instrument,  $h_b'$  can be taken as correct reading.

Correct reading at A =  $h_a' - e$

Difference in elevations  $H = (h_a' - e) - h_b'$  ... (ii)

From equations (i) and (ii) we get,

$$2 H = h_a - (h_b - e) + (h_a' - e) - h_b'$$

$$= (h_a + h_a') - (h_b + h_b')$$

$\therefore H = \frac{(h_a + h_a') - (h_b + h_b')}{2}$  ... (15.1)

Thus, the true difference in the elevations of the two points is equal to the mean of the two apparent differences in the elevations.

■ **Example 15.1:** The following staff readings were observed successively with a level. The instrument has been shifted after the second and fifth reading: 0.675, 1.230, 0.750, 2.565, 2.225, 1.935, 1.835, 3.220. The first reading was with staff held on benchmark of RL 100.000 m. Enter the readings in a page of level book and calculate the RL of all points. Apply arithmetic checks. Use plane of collimation method.

**Solution:** It is carried out as shown in Table 15.5.

**Table 15.5**

Station	BS	IS	FS	Plane of Collimation	RL	Remarks
	0.675			100.675	100.00	BM of RL = 100.00
	0.750		1.230	100.195	99.445	CP <sub>1</sub>
		2.565			97.630	
	1.935		2.225	99.905	97.970	CP <sub>2</sub>
		1.835			98.070	
			3.220		96.685	Last Point
$\Sigma$ BS = 3.360		$\Sigma$ FS = 6.675		Last RL – first RL		
$\Sigma$ BS – $\Sigma$ FS = – 3.315 (Fall)					= – 3.315 (Fall)	Checked

■ **Example 15.2:** Reduce the levels in example 15.1 by rise and fall method.

**Solution:** It is carried out as shown in Table 15.6 below:

Table 15.6

Station	BS	IS	FS	Rise	Fall	RL	Remarks
	0.675					100.00	BM
	0.750		1.230		0.555	99.445	CP <sub>1</sub>
		2.565			1.815	97.630	
	1.935		2.225	0.340		97.970	CP <sub>2</sub>
		1.835		0.100		98.070	
			3.220		1.385	96.685	Last point
$\Sigma$	3.360		6.675	0.440	3.755		
$\therefore$	$\Sigma BS - \Sigma FS = -3.315$		$\Sigma Rise - \Sigma Fall = -3.315$		$RL \text{ of last point} - RL \text{ of first point} = -3.315$ Checked.		

■ **Example 15.3:** The following consecutive readings were taken with a level on a sloping ground at a common interval of 20 m.

0.600, 1.235, 1.860, 2.575, 0.235, 0.915, 1.935 and 2.870.

The reduced level of the first point was 192.125 m. Rule out a page of level book and enter the above readings. Calculate the reduced levels of points. Apply the check.

**Solution:** Table 15.7 shows entries in typical page of level book and method of reducing the levels.

Table 15.7

Station	Distance			Readings			Plane of Collimation	RL	Remarks
	L	C	R	BS	IS	FS			
A		0.0		0.600			192.725	192.125	First point
		20.0			1.235			191.149	
		40.0			1.860			190.865	
		60.0			2.575			190.150	
		80.0			0.235			192.490	
		100.0			0.915			191.810	
		120.0				2.870		189.855	Last point
				$\Sigma BS = 0.600$	$\Sigma FS = 2.870$	RL of last point			
				$\Sigma BS - \Sigma IS = -2.270$			- RL of first point = -2.27 Checked		

■ **Example 15.4:** Reciprocal levelling was conducted with a dumpy level and the following readings were recorded.

Instrument near	Staff reading at	
	A	B
A	1.245	1.575
B	1.050	0.700

Compute the RL of B, if RL of A = 218.250 m.

**Solution:**  $h_a = 1.245$  m  $h_b = 1.575$  m  
 $h'_a = 1.505$  m  $h'_b = 0.700$  m

∴ Difference in levels of A and B is

$$= \frac{(h_a - h_b) + (h'_a - h'_b)}{2}$$

$$= \frac{(1.245 - 1.575) + (1.050 - 0.700)}{2} = 0.01 \text{ m}$$

Plane of collimation at A = 218.250 + 1.245  
 = 219.495 m

∴ **Elevation of B** = 219.495 – 0.01  
 = **219.485 m Ans.**

## QUESTIONS

- Define the following terms used in levelling:
  - Benchmark
  - Level line
  - Change point
  - Mean sea level.
- Differentiate between:
  - GTS benchmark and Temporary benchmark
  - Fore sight and back sight
  - Plane of collimation and RL of a point
  - Fly levelling and profile levelling.
- What are the temporary adjustments of dumpy level ? Explain how they are performed.
- Write short notes on Barometric levelling and Hypsometry.
- Explain differential levelling.
- Write short note on reciprocal levelling.
- The following staff readings were taken with a level, the instrument having been moved after third and sixth reading:
 

2.200   1.620   0.980   2.250   2.840   1.280   0.600   1.960   1.450

The RL of first point is 100.00 m. Rule out a page of level book and enter the above readings. Calculate the RL of all points. Apply the checks. **[Ans: RL of last point 101.34.]**

**[Note.** First, fourth and seventh readings are back sights. Third, sixth and last readings are fore sights].



## Modern Tools of Surveying

Theodolite is an instrument which replaced compass and level. It can measure both horizontal and vertical angles. If telescope is kept at zero reading of vertical angle it serves as an ordinary level. In this modern era of electronics equipments have come up to measure the distances to relieve surveyor from chaining long lines. Total station is another modern survey equipment which combines the features of theodolite and electromagnetic distance measurement (EDM) instruments. Global positioning system is an instrument, which establishes global position of the station making use at least 4 satellite stations. In this chapter all these modern tools of surveying are briefly explained.

### 16.1 THEODOLITE

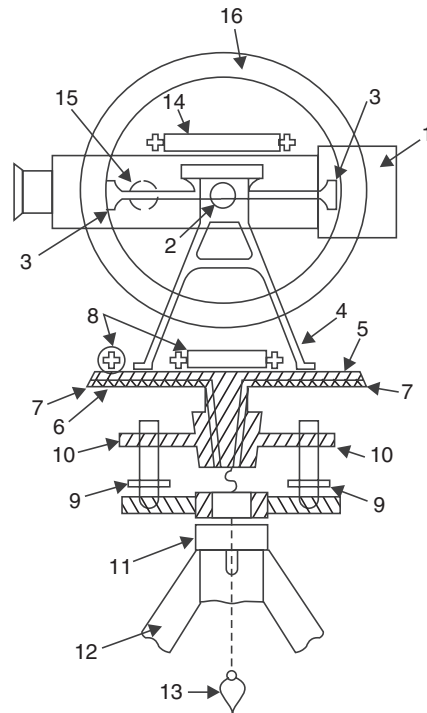
It is a commonly used instrument for measuring horizontal and vertical angles. It is used for prolonging a line, levelling and even for measuring the distances indirectly (techeometry). Using verniers angles can be read accurately up to 20". Precise theodolites are available which can read angles up to even 1" accuracy. They use optical principle for more accurate instruments. Now a days electronic theodolites are also available which display the angles.

In this article construction and use of vernier theodolite is explained.

#### 16.1.1 Parts of a Vernier Theodolite

Figure 16.1 shows a sectional view of a typical vernier theodolite and plate 16.1 shows photograph of such theodolite. Main parts of such a theodolite are:

- 1. Telescope:** A telescope is mounted on a horizontal axis (trunnian axis) hence it can rotate in vertical plane. Its length varies from 100 mm 175 mm and its diameter is 38 mm at objective end. Its functions is to provide a line of sight.



- |                         |                     |
|-------------------------|---------------------|
| 1. Telescope            | 9. Foot crews       |
| 2. Trunnian axis        | 10. Levelling head  |
| 3. Vernier frame        | 11. Tripod head     |
| 4. Standards or A-Frame | 12. Tripod          |
| 5. Upper plate          | 13. Plumb bob       |
| 6. Lower plate          | 14. Altitude level  |
| 7. Vernier              | 15. Focussing screw |
| 8. Plate level          | 16. Vertical circle |

Fig. 16.1. Sectional view of a transit theodolite

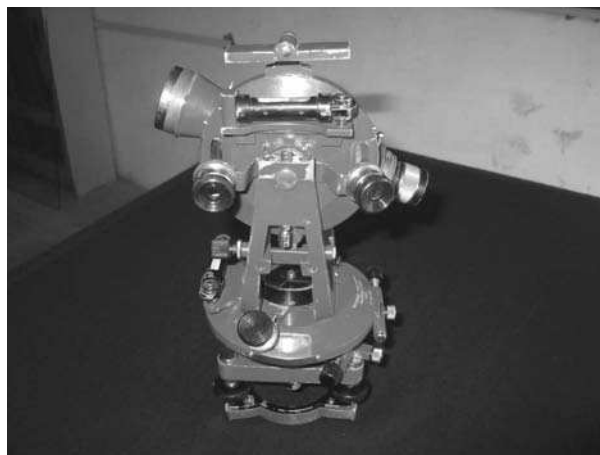


Plate 16.1 Theodolite

2. **Vertical Circle:** A vertical circle graduated up to an accuracy of  $20'$  is rigidly connected to the telescope and hence moves with it when the telescope is rotated in vertical plane. The graduations are in quadrantal system, 0-0 line being horizontal (Ref. Fig. 16.2).

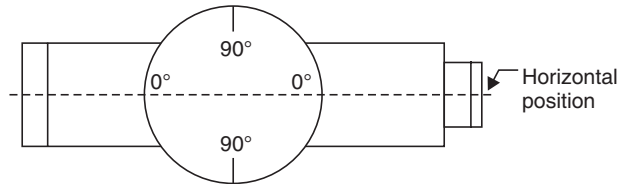


Fig. 16.2

3. **Vernier Frame:** It is a T-shaped frame (Fig. 16.3) consisting of a vertical arm and a horizontal arm. With the help of the clamping screws the vertical frame and hence the telescope can be clamped at desired angle. Vertical frame is also known as **T-frame** or **index frame**. The vernier arm is known as index arm. At the ends it carries verniers C and D so as to read graduations on vertical circle. They are provided with glass magnifiers. Altitude bubble tube is fitted over the horizontal arm.

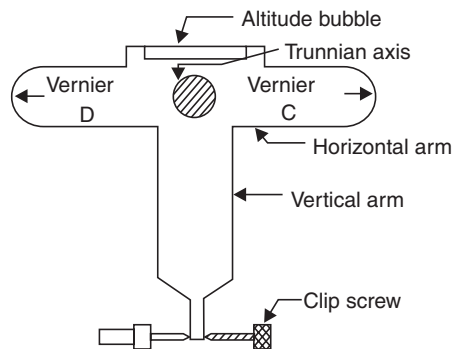


Fig. 16.3

4. **Standards or A-Frame:** The frames supporting telescope are in the form of English letter 'A'. This frame allows telescope to rotate on its trunnian axis in vertical frame. The T-frame and the clamps are also fixed to this frame.
5. **Upper Plate [Fig. 16.4]:** Upper plate supports standards on its top surface. On lower side it is attached to a inner spindle which rotates in the outer spindle of lower plate. Using upper clamp, upper plate can be clamped to lower plate. Using tangent screws, it is possible to give slight relative motion between the two plates, even after clamping. Two diametrically opposite verniers A and B fixed to upper plate help in reading horizontal circle graduations. They are provided with magnifying glasses.

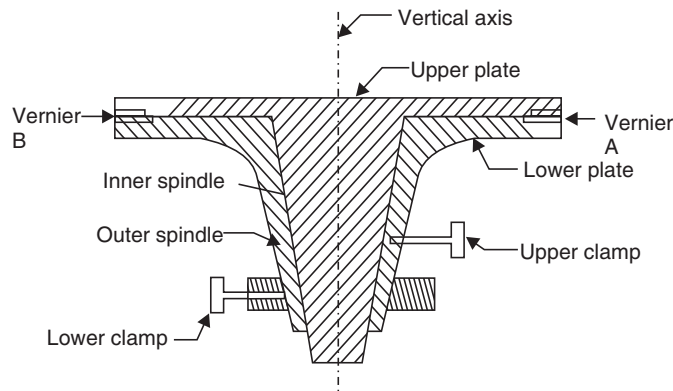


Fig. 16.4

6. **Lower Plate:** The lower plate, attached to the outer spindle carries a graduated circle at its bevelled edge. Graduations are up to an accuracy of 20'. It can be clamped at any desired position using lower clamps. If upper clamp is locked and the lower one is loosened the two plates rotate together. If the upper clamp is loosened and lower clamp locked, upper plate alone rotates. This mechanism is utilised in measuring horizontal angle.
7. **Plate Level:** One or two plate level tubes are mounted on the upper plate. If the two level tubes are provided they will be at right angles to each other one of them being parallel to trunnion axis. These levels help in making the vertical axis of the instrument truly vertical.
8. **Levelling Head:** It consists of two parallel triangular plates known as *tribratch plates*. The upper tribratch plate is provided with three levelling screws—each one carried by a arm of tribratch plate. By operating screws the levelling of upper plate and hence telescope can be ensured. The lower tribratch can be fitted into a tripod head.
9. **Tripod:** Theodolite is always used by mounting it on a tripod. The legs of tripod may be solid or framed. At the lower end the legs are provided with steel shoes to get good grip with the ground. The top of tripod is provided with external screw to which the lower tribratch plate can be screwed. When not in use tripod head may be protected with a steel cap, provided for this purpose.
10. **Plumb Bob:** A hook is provided at the middle of lower tribratch plate from which a plumb bob can be suspended. It facilitates exact centering of the theodolite on a station.
11. **Shifting Head:** It is provided below the lower plate. In this, one plate slides over another over a small area of about 10 mm radius. The two plates can be tightened in the desired position. It facilitates exact centering of the instruments.
12. **Magnetic Compass:** In some theodolites a magnetic compass is fixed on one of the strands. It is useful if readings are to be recorded with magnetic north as meridian.

### 16.1.2 Use of Theodolite

Theodolite is used for measuring horizontal and vertical angles. For this the theodolite should be centered on the desired station point, levelled and telescope is focussed. This process of centering, levelling and focussing is called temporary adjustment of the instrument.

### Measurement of Horizontal Angle

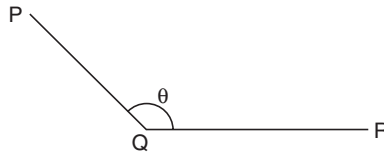


Fig. 16.5

The procedure is explained for measuring horizontal angle  $\theta = \text{PQR}$  at station Q (Ref. Fig. 16.5)

1. Set the theodolite at Q with vertical circle to the left of the line of sight and complete all temporary adjustments.
2. Release both upper and lower clamps and turn upper plate to get  $0^\circ$  on the main scale. Then clamp main screw and using tangent screw get exactly zero reading. At this stage vernier A reads  $0^\circ$  and vernier B reads  $180^\circ$ .
3. Through telescope take line of sight to signal at P and lock the lower clamp. Use tangent screw for exact bisection.
4. Release the upper clamp and swing telescope to bisect signal at R. Lock upper clamp and use tangent screen to get exact bisection of R.
5. Read verniers A and B. The reading of vernier A gives desired angle PQR directly, while  $180^\circ$  is to be subtracted from the reading of vernier B to get the angle PQR.
6. Transit (move by  $180^\circ$  in vertical plane) the telescope to make vertical circle to the right of telescope. Repeat steps 2 to 5 to get two more values for the angle.
7. The average of 4 values found for  $\theta$ , give the horizontal angle. Two values obtained with face left and two obtained with face right position of vertical circle are called one set of readings.
8. If more precision is required the angle may be measured **repeatedly**. *i.e.*, after step 5, release lower clamp, sight signal at P, then lock lower clamp, release upper clamp and swing the telescope to signal at Q. The reading of vernier A doubles. The angle measured by vernier B is also doubled. Any number of repetitions may be made and average taken. Similar readings are then taken with face right also. Finally average angle is found and is taken as desired angle 'Q'. This is called **method of repetition**.
9. There is another method of getting precise horizontal angles. It is called **method of reiteration**. If a number of angles are to be measured from a station this technique is used (Fig. 16.6). With zero reading of vernier A signal at P is sighted exactly and lower clamp and its tangent screw are locked. Then  $\theta_1$  is measured by sighting Q and noted. Then  $\theta_2$ ,  $\theta_3$  and  $\theta_4$  are measured by unlocking upper clamp and bisecting signals at R, S and P. The angles are calculated and checked to see that sum is  $360^\circ$ . In each case both verniers are read and similar process is carried out by changing the face (face left and face right).

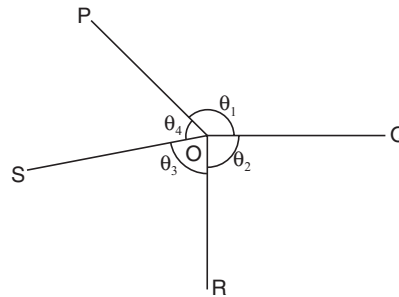


Fig. 16.6

**Measurement of Vertical Angle**

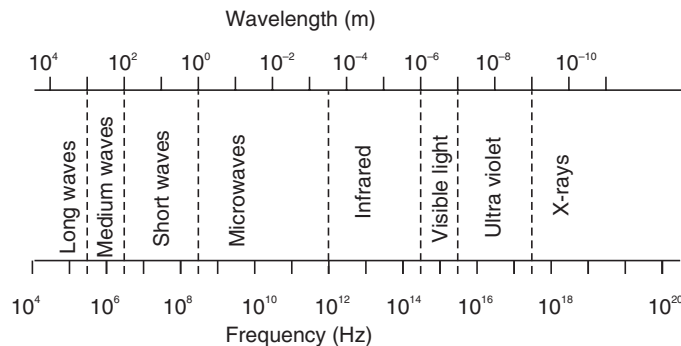
Horizontal sight is taken as zero vertical angle. Angle of elevations are noted as +ve angles and angle of depression as -ve angles.

To measure vertical angle the following procedure may be followed:

1. Complete all temporary adjustment at the required station.
2. Take up levelling of the instrument with respect to altitude level provided on the A – frame. This levelling process is similar to that used for levelling dumpy level *i.e.*, first altitude level is kept parallel to any two levelling screws and operating those two screws bubble is brought to centre. Then by rotating telescope, level tube is brought at right angles to the original position and is levelled with the third screw. The procedure is repeated till bubble is centred in both positions.
3. Then loosen the vertical circle clamp, bisect P and lock the clamp. Read verniers C and D to get vertical angle. Take the average as the actual vertical angle.

**16.2 ELECTROMAGNETIC DISTANCE MEASURING INSTRUMENTS**

Sun light or artificially generated electromagnetic waves consists of waves of different lengths. The spectrum of an electromagnetic wave is as shown below:



Among these waves microwaves, infrared waves and visible light waves are useful for the distance measurement. In EDM instruments these waves are generated, modulated and then propagated. They are reflected at the point up to which distance is to be measured from the instrument station and again received by the instrument. The time taken by the wave to travel this  $2x$  distance may be measured and knowing the velocity of wave, the distance may be calculated. However time is too short, measuring the time taken is difficult. The improved techniques use phase difference method in which the number of completed wave and incomplete wave is measured. Knowing the length of wave, distances are calculated. Built up microprocessors provided in the instrument calculate the distances and display it by liquid crystal display (LCD).

EDM instruments may be classified into the following three types:

1. Micro wave instruments
2. Infrared wave instruments
3. Light wave instruments.

### 16.2.1 Micro Wave Instruments

These instruments make use of micro waves. Such instruments were invented as early as 1950 in South Africa by Dr. T.L. Wadley and named them as Tellurometers. The instrument needs only 12 to 24 V batteries. Hence they are light and highly portable. Tellurometers can be used in day as well as in night. The range of these instrument is up to 100 km. It consists of two identical units. One unit is used as master unit and the other as remote unit. Just by pressing a button, a master unit can be converted into a remote unit and a remote unit into a master unit. It needs two skilled persons to operate. A speech facility is provided to each operator to interact during measurements.

### 16.2.2 Infrared Wave Instruments

In these instrument amplitude modulated infrared waves are used. Prism reflectors are used at the end of line to be measured. These instruments are light and economical and can be mounted on theodolite. With these instruments accuracy achieved is  $\pm 10$  mm. The range of these instruments is up to 3 km. These instruments are useful for most of the civil engineering works. These instruments are available in the trade names DISTOMAT DI 1000 and DISTOMAT DI 55.

### 16.2.3 Light Wave Instruments

These instruments rely on propagation of modulated light waves. This type of instrument was first developed in Sweden and was named as Geodimeter. During night its range is up to 2.5 km while in day its range is up to 3 km. Accuracy of these instruments varies from 0.5 mm to 5 mm/km distance. These instruments are also very useful for civil engineering projects.

The advantage of using EDM instruments is the speed and accuracy in measurement. Several obstacles to chaining are automatically overcome when these instruments are used.

### 16.3 TOTAL STATION

It is combination of EDM instrument and electronic theodolite. It is also integrated with microprocessor, electronic data collector and storage system. The instrument can be used to measure horizontal and vertical angles as well as sloping distance of object to the instrument. Microprocessor unit processes the data collected to compute:

1. average of multiple angles measured
2. average of multiple distance measured
3. horizontal distance
4. distance between any two points
5. elevation of objects and
6. all the three coordinates of the observed points.

Data collected and processed may be down-loaded to computers for further processing. Total station is a compact instrument and weighs 50 to 55 N. A person can easily carry it to the field. Total stations with different accuracies, in angle measurement and different range of measurements are available in the market. Figure 16.7 shows one such instrument manufactured by SOKKIA Co. Ltd. Tokyo, Japan.

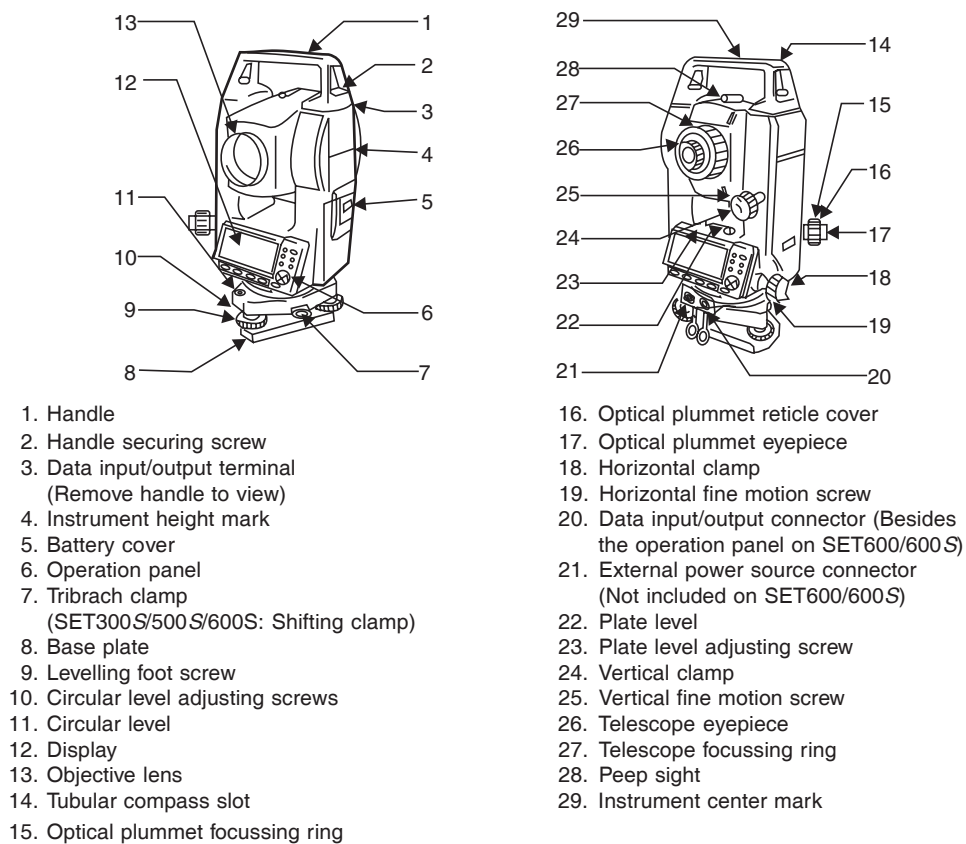


Fig. 16.7. Parts of total station



### Brief Description of Important Operations

*Distance Measurement:* Electronic distance measuring (EDM) instrument is a major part of total station. Its range varies from 2.8 km to 4.2 km. The accuracy of measurement varies from 5 mm to 10 mm per km measurement. They are used with automatic target recognisers. The distance measured is always sloping distance from instrument to the object.

*Angle Measurements:* The electronic theodolite part of total station is used for measuring vertical and horizontal angle. For measurement of horizontal angles any convenient direction may be taken as reference direction. For vertical angle measurement vertical upward (zenith) direction is taken as reference direction. The accuracy of angle measurement varies from 2 to 6 seconds.

*Data Processing :* This instrument is provided with an inbuilt microprocessor. The microprocessor averages multiple observations. With the help of slope distance and vertical and horizontal angles measured, when height of axis of instrument and targets are supplied, the microprocessor computes the horizontal distance and X, Y, Z coordinates. The processor is capable of applying temperature and pressure corrections to the measurements, if atmospheric temperature and pressures are supplied.

*Display:* Electronic display unit is capable of displaying various values when respective keys are pressed. The system is capable of displaying horizontal distance, vertical distance, horizontal and vertical angles, difference in elevations of two observed points and all the three coordinates of the observed points.

*Electronic Book:* Each point data can be stored in an electronic note book (like compact disc). The capacity of electronic note book varies from 2000 points to 4000 points data. Surveyor can unload the data stored in note book to computer and reuse the note book.

### Use of Total Station

The instrument is mounted on a tripod and is levelled by operating levelling screws. Within a small range instrument is capable of adjusting itself to the level position. Then vertical and horizontal reference directions are indexed using onboard keys. It is possible to set required units for distance, temperature and pressure (FPS or SI). Surveyor can select measurement mode like fine, coarse, single or repeated. When target is sighted, horizontal and vertical angles as well as sloping distances are measured and by pressing appropriate keys they are recorded along with point number. Heights of instrument and targets can be keyed in after measuring them with tapes. Then processor computes various information about the point and displays on screen. This information is also stored in the electronic note book. At the end of the day or whenever electronic note book is full, the information stored is downloaded to computers.

The point data downloaded to the computer can be used for further processing. There are software like auto civil and auto plotter clubbed with autocad which can be used for plotting contours at any specified interval and for plotting cross-section along any specified line.

### Advantages of Using Total Stations

The following are some of the major advantages of using total station over the conventional surveying instruments:

1. Field work is carried out very fast.
2. Accuracy of measurement is high.
3. Manual errors involved in reading and recording are eliminated.
4. Calculation of coordinates is very fast and accurate. Even corrections for temperature and pressure are automatically made.
5. Computers can be employed for map making and plotting contour and cross-sections. Contour intervals and scales can be changed in no time.

However, surveyor should check the working condition of the instruments before using. For this standard points may be located near survey office and before taking out instrument for field work, its working is checked by observing those standard points from the specified instrument station.

## 16.4 GLOBAL POSITIONING SYSTEM

The station points used in surveying are to be identified before executing any project: For this purpose, surveyors used permanent objects as reference points and made reference sketches of station points. Navigators used sun and stars as references. Sometimes when the project is taken up the so called permanent object (like building corner) may not exist when the execution of project work is taken up. For navigations weather conditions may obstruct the observations. Now a days this problem is overcome by using an instrument called Global Positioning System (GPS). This was developed by United States defence department and was called as Navigational System with Time and Ranging Global Positioning System (NAVSTAR) or which is now simply known as GPS.

There are 24 geostationary satellites positioned around the earth by US air force. These satellites are used as reference points to locate any point on the earth. These satellites are at an altitude of 20200 km above the earth. The 24 satellites are positioned such that from any point on the earth a minimum of 4 satellites are visible.

A user needs only GPS receiver. The receiver measures the travel time of the signals from satellites and calculate position (latitude and longitude) and the elevation altitude of the station with reference to a selected datum. The advantages of using GPS are:

1. Can be used in day as well as in night.
2. Intervisibility of the two stations on the earth is not a requirement.
3. Time required to establish the position of a point is much less.
4. Man power required is less.
5. Accuracy is high. Most expensive GPS provide accuracies within 10 mm.

### Uses of GPS

GPS is very useful in

1. Marine navigation
2. Airborne aviation

3. Surveying of land.
4. Sports such as yatching, hiking.
5. The sophistication of GPS has improved so much that drivers of automobiles can get directions to their destinations easily on the screen.

## QUESTIONS

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1. Explain how you measure horizontal angle with a theodolite?
2. What is meant by face left and face right readings in theodolite survey?
3. What is meant by method of repetition and method of reiteration in theodolite survey?
4. Write short notes on the following:
  - (a) EDM instruments
  - (b) Total station
  - (c) Global positioning system.

# **UNIT - IV**

## **MAPPING AND SENSING**

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## Mapping And Contouring

As stated earlier the aim of surveying is to make plans and maps to show various objects on the ground at their relative position to suitable scale. Various steps involved in making the plans is explained in this chapter. Contouring is the technique of showing the levels of ground in a plan. This technique is also explained in this article.

### 17.1 MAPPING

After completing field work in chain survey and compass survey lot of office work is involved to prepare the plan of the area surveyed. In plane table survey office work is less. The office work involved consist of

1. Applying necessary corrections to measurements
2. Drawing index plan
3. Selecting scale
4. Selecting orientation
5. Drawing network of survey lines
6. Distributing closing error
7. Filling in the details
8. Colouring the map
9. Drawing graphical scale
10. Writing index.

#### 17.1.1 Applying Necessary Corrections to Measurements

Necessary tape and chain corrections and corrections for local attraction in case of compass survey, should be applied to the survey lines measured.

### 17.1.2 Drawing Index Plan

On a rough sheet index plan also known as key plan is drawn. This need not be to the scale but distances and directions of network of survey lines should be approximately to a scale. This plan is necessary to identify the shape of the area to be plotted.

### 17.1.3 Selecting Scale

Depending upon the type of survey, scale should be selected. In general, scale selected should be as large as possible, if a range of scale is recommended. It depends upon the size of the paper as well as largest linear measurement in the field.

### 17.1.4 Selecting Orientation

Looking at index plan, orientation of map is to be decided so that the map is placed in the middle of the drawing sheet with its larger dimension approximately along the length of paper. North direction is selected and marked.

### 17.1.5 Drawing Network of Survey Lines

Studying index map and orientation of paper, first station point of survey is marked. Starting from here one by one survey line is drawn to the scale in its direction. After drawing all survey lines, it is clearly seen whether the selected scale and orientation appropriate. If necessary they may be changed and network of survey lines is redrawn.

### 17.1.6 Distributing Closing Error

Sometimes in closed traverse, the last point may not coincide with the plotted position of first point. The difference between the plotted position is known as closing error. Before adjusting closing error it is necessary that there are no plotting errors. If it is due to field work error and the error is reasonably small it can be adjusted in the office. If error is large, one has to go back to the field and check doubtful measurements. In the office closing error is adjusted distributing it suitably to all lines graphically or by mathematical calculation of corrected coordinates of station points. After adjusting closing error network of survey lines are drawn as per the convention.

### 17.1.7 Filling in the Details

Surveyor has to go through details of one by one survey lines. One by one point of object noted in the field is marked on the drawing sheet by converting the change and offsets to the scale. Main scale and offset scales will be quite useful for this work. After marking the salient points of the objects like building, boundary lines, roads, culvert ends, trees, electric poles etc. the respective lines are joined to mark the object. The field book will be useful in identifying the objects. If the object is building, the measurements may be only for salient points near the survey lines looking at overall dimensions of the building and scaling down, complete building may be shown in the plan. Thus attending to the field observations of each survey lines all details may be shown. Standard conventions should be used in showing the objects.

### 17.1.8 Colouring the Map

If coloured maps are to be made, the recommended light washes of standard shades as listed in IS 962-1989 (Chapter 7) may be applied.

### 17.1.9 Drawing Graphical Scale

As the drawing sheet may shrink and the measurement taken from shrunk sheet may mislead the distances between any two objects on the map, it is necessary to draw a graphical scale of 150 to 270 mm long just over the space for indexing the drawing, which is right hand side lower corner of the sheet.

### 17.1.10 Writing Index

Index is the details giving the description of the area plotted, scale used, name of leader of survey party and the person drawing the plan/map. etc. It is normally written in the right hand side lower corner of the drawing sheet. North direction is shown neatly at the right hand side top corner.

## 17.2 CONTOURS

A contour line is a imaginary line which connects points of equal elevation. Such lines are drawn on the plan of an area after establishing reduced levels of several points in the area. The contour lines in an area are drawn keeping difference in elevation of between two consecutive lines constant. For example, Fig. 17.1 shows contours in an area with contour interval of 1 m. On contour lines the level of lines is also written.

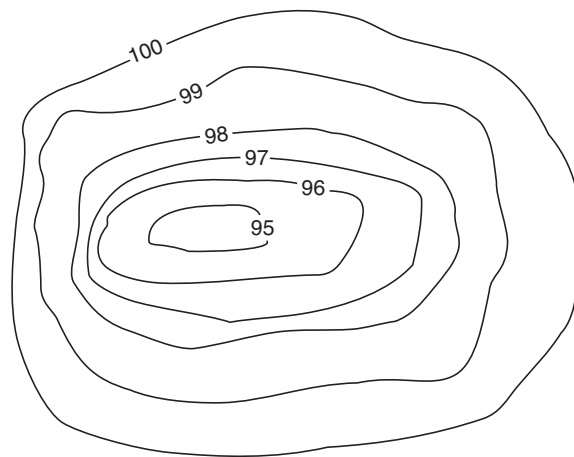


Fig. 17.1. Contours

### 17.2.1 Characteristics of Contours

The contours have the following characteristics:

1. Contour lines must close, not necessarily in the limits of the plan.
2. Widely spaced contour indicates flat surface.



3. Closely spaced contour indicates steep ground.
4. Equally spaced contour indicates uniform slope.
5. Irregular contours indicate uneven surface.
6. Approximately concentric closed contours with decreasing values towards centre (Fig. 17.1) indicate a pond.
7. Approximately concentric closed contours with increasing values towards centre indicate hills.
8. Contour lines with U-shape with convexity towards lower ground indicate ridge (Fig. 17.2).

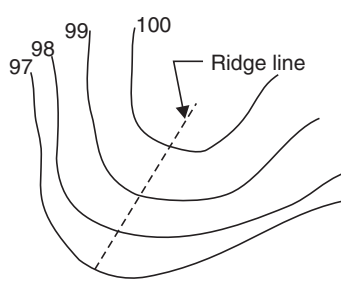


Fig. 17.2

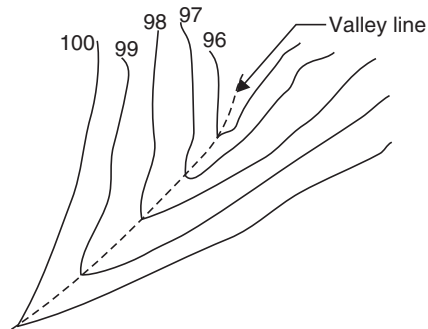


Fig. 17.3

9. Contour lines with V-shaped with convexity towards higher ground indicate valley (Fig. 17.3).
10. Contour lines generally do not meet or intersect each other.
11. If contour lines are meeting in some portion, it shows existence of a vertical cliff (Fig. 17.4).

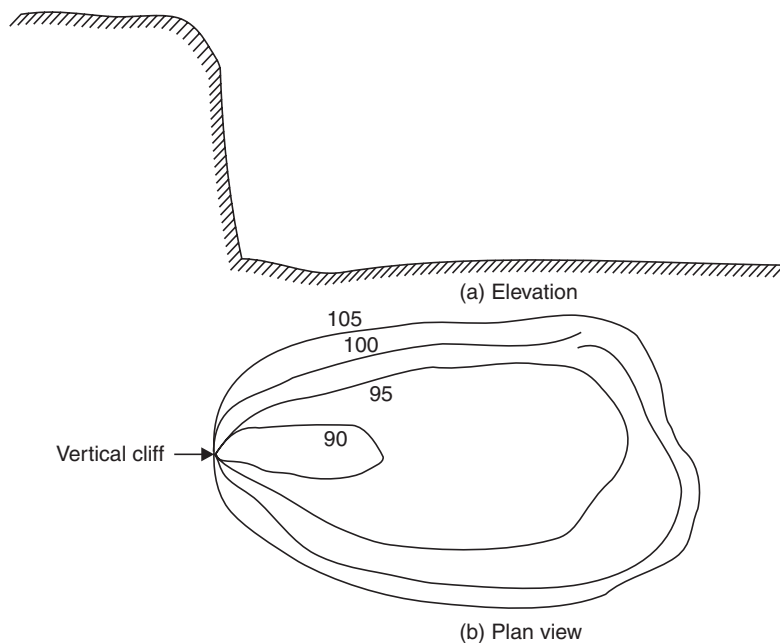


Fig. 17.4

12. If contour lines cross each other, it shows existence of overhanging cliffs or a cave (Fig. 17.5).

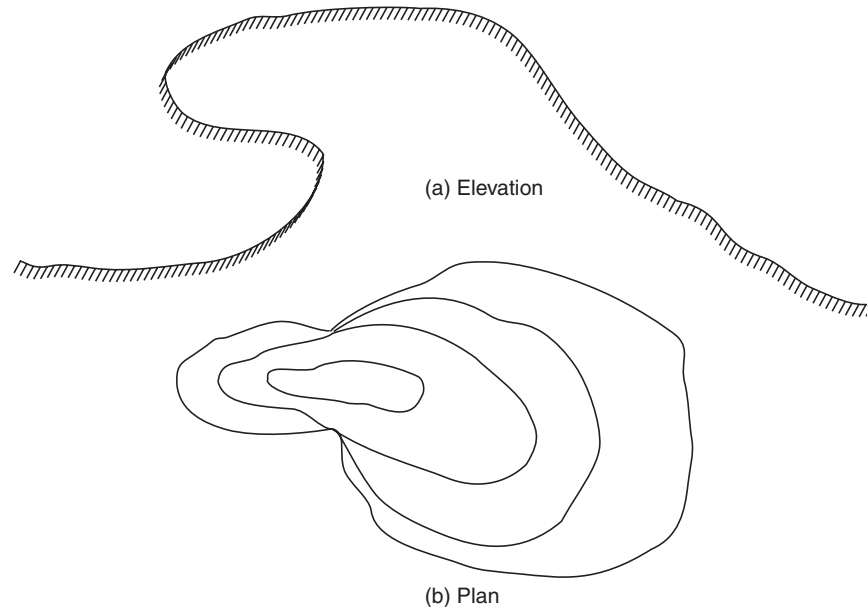


Fig. 17.5

### 17.2.2 Uses of Contour Maps

Contour maps are extremely useful for various engineering works:

1. A civil engineer studies the contours and finds out the nature of the ground to identify. **Suitable site for the project** works to be taken up.
2. By **drawing the section** in the plan, it is possible to find out profile of the ground along that line. It helps in finding out depth of cutting and filling, if formation level of road/railway is decided.
3. **Intervisibility of any two points** can be found by drawing profile of the ground along that line.
4. **The routes** of the railway, road, canal or sewer lines can be decided so as to minimize and balance earthworks.
5. **Catchment area** and hence quantity of water flow at any point of nalla or river can be found. This study is very important in locating bunds, dams and also to find out flood levels.
6. From the contours, it is possible to determine the **capacity of a reservoir**.

## 17.3 METHODS OF CONTOURING

Contouring needs the determination of elevation of various points on the ground and at the same the horizontal positions of those points should be fixed. To exercise vertical control levelling work is carried out and simultaneously to exercise horizontal control chain survey or compass survey or plane table survey is to be carried out. If the theodolite is used both horizontal and vertical controls can be achieved from the same instrument. Based on the instruments used one can classify the contouring in different groups.

However, broadly speaking there are two methods of surveying:

1. Direct methods
2. Indirect methods.

### 17.3.1 Direct Methods

It consists in finding vertical and horizontal controls of the points which lie on the selected contour line.

For vertical control levelling instrument is commonly used. A level is set on a commanding position in the area after taking fly levels from the nearby bench mark. The plane of collimation/height of instrument is found and the required staff reading for a contour line is calculated. The instrument man asks staff man to move up and down in the area till the required staff reading is found. A surveyor establishes the horizontal control of that point using his instruments. After that instrument man directs the staff man to another point where the same staff reading can be found. It is followed by establishing horizontal control. Thus several points are established on a contour line on one or two contour lines and suitably noted down. Plane table survey is ideally suited for this work. After required points are established from the instrument setting, the instrument is shifted to another point to cover more area. The level and survey instrument need not be shifted at the same time. It is better if both are nearby so as to communicate easily. For getting speed in levelling some times hand level and Abney levels are also used. This method is slow, tedious but accurate. It is suitable for small areas.

### 17.3.2 Indirect Methods

In this method, levels are taken at some selected points and their levels are reduced. Thus in this method horizontal control is established first and then the levels of those points found. After locating the points on the plan, reduced levels are marked and contour lines are interpolated between the selected points. For selecting points anyone of the following methods may be used:

- (a) Method of squares,
- (b) Method of cross-section, or
- (c) Radial line method.

**Method of Squares:** In this method area is divided into a number of squares and all grid points are marked (Ref. Fig. 17.6). Commonly used size of square varies from 5 m × 5 m to

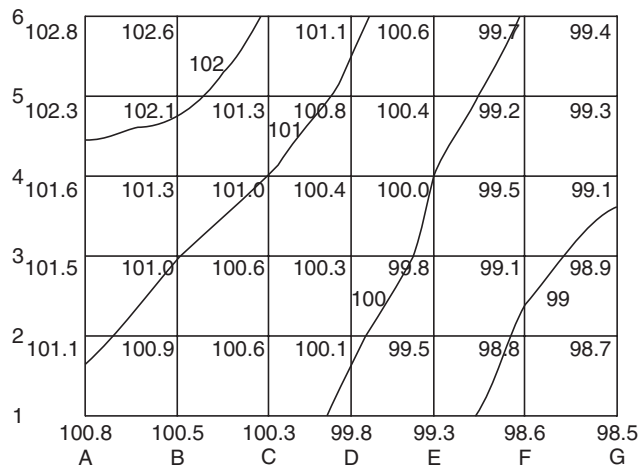


Fig. 17.6

20 m × 20 m. Levels of all grid points are established by levelling. Then grid square is plotted on the drawing sheet. Reduced levels of grid points marked and contour lines are drawn by interpolation [Ref. Fig. 17.6].

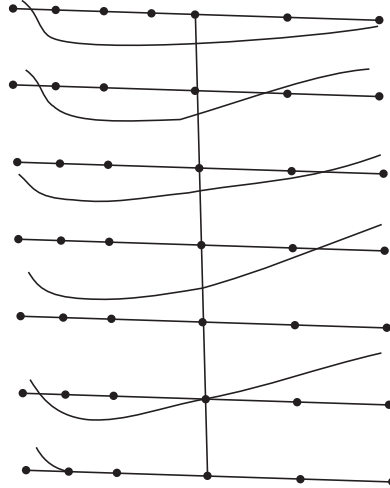


Fig. 17.7

**Method of Cross-section:** In this method cross-sectional points are taken at regular interval. By levelling the reduced level of all those points are established. The points are marked on the drawing sheets, their reduced levels (RL) are marked and contour lines interpolated. Figure 17.7 shows a typical planning of this work. The spacing of cross-section depends upon the nature of the ground, scale of the map and the contour interval required. It varies from 20 m to 100 m. Closer intervals are required if ground level varies abruptly. The cross-sectional line need not be always be at right angles to the main line. This method is ideally suited for road and railway projects.

**Radial Line Method:** [Fig. 17.8]. In this method several radial lines are taken from a point in the area. The direction of each line is noted. On these lines at selected distances points are marked and levels determined. This method is ideally suited for hilly areas. In this survey theodolite with tacheometry facility is commonly used.

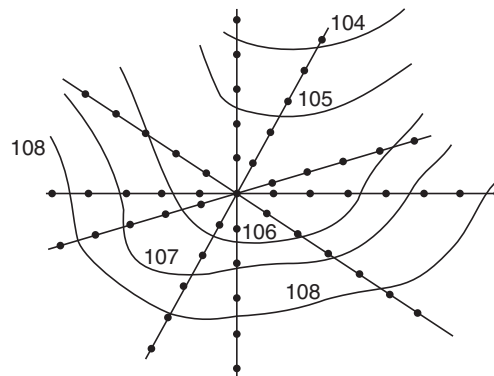


Fig. 17.8

For *interpolating contour* points between the two points any one of the following method may be used:

- (a) Estimation  
(b) Arithmetic calculation  
(c) Mechanical or graphical method.

Mechanical or graphical method of interpolation consist in linearly interpolating contour points using tracing sheet:

On a tracing sheet several parallel lines are drawn at regular interval. Every 10th or 5th line is made darker for easy counting. If RL of A is 97.4 and that of B is 99.2 m. Assume the bottom most dark line represents. 97 m RL and every parallel line is at 0.2 m intervals. Then hold the second parallel line on A. Rotate the tracing sheet so that 100.2 the parallel line passes through point B. Then the intersection of dark lines on AB represent the points on 98 m and 99 m contours [Ref. Fig. 17.9]. Similarly the contour points along any line connecting two neighbouring points may be obtained and the points pricked. This method maintains the accuracy of arithmetic calculations at the same time it is fast.

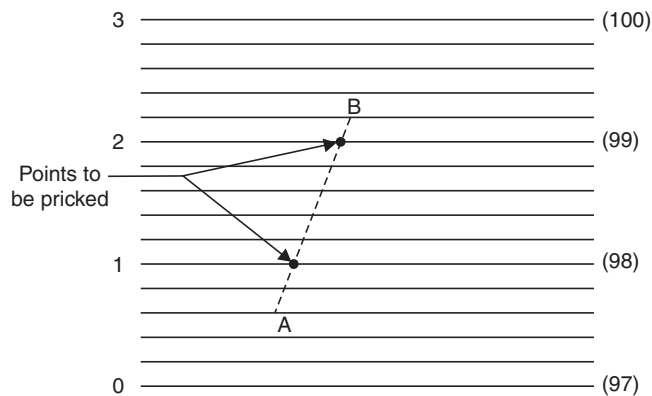


Fig. 17.9

### Drawing Contours

After locating contour points smooth contour lines are drawn connecting corresponding points on a contour line. French curves may be used for drawing smooth lines. A surveyor should not lose the sight of the characteristic feature on the ground. Every fifth contour line is made thicker for easy readability. On every contour line its elevation is written. If the map size is large, it is written at the ends also.

### QUESTIONS

1. Explain the step by step procedure of mapping area surveyed.
2. Explain the terms 'contour lines' and 'contour intervals'.
3. List the characteristics of contours.
4. Sketch the typical contours for the following:
  - (a) Valley
  - (b) Ridge
  - (c) Vertical cliff
  - (d) Overhanging cliff.
5. List the various uses of contour maps.

## Areas and Volumes

The land is always bought and sold on the basis of cost per unit area. For road and railways land is to be acquired on the basis of area. In the design of bridges and bunds catchment area of river and nalla are required. Thus finding areas is the essential part of surveying. It may be noted that area to be found is the projected area. Units used for finding areas are square metres, hectare and square kilometre. Relation among them are

$$\text{Hectare} = 100 \text{ m} \times 100 \text{ m} = 1 \times 10^4 \text{ m}^2$$

$$\begin{aligned} \text{Square kilometer} &= 1000 \text{ m} \times 1000 \text{ m} = 1 \times 10^6 \text{ m}^2 \\ &= 100 \text{ hectare} \end{aligned}$$

Similarly volume of earth work involved in projects like road, rail and canal are to be found by surveying. Capacity of reservoir also need volume calculations. In this chapter calculation of areas and volumes based on surveying are explained.

### 18.1 COMPUTATION OF AREAS FROM FIELD NOTES

If the area is bound by straight edges, it can be subdivided in a set of convenient figures and area calculated. But in most of the cases the boundary may have irregular shape. In such cases major area is subdivided into regular shape and area is found. The smaller area near the boundary is found from taking offset from a survey line [Ref. Fig. 18.1].

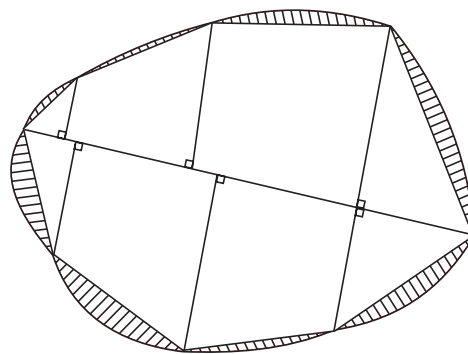


Fig. 18.1

### 18.1.1 Computation of Areas of Regular Figures

The following expressions for calculating areas may be noted:

(a) **Triangle:**

(i) If base width is  $b$  and height is ' $h$ ',

$$A = \frac{1}{2} bh \quad \dots(18.1)$$

(ii) If  $a$ ,  $b$  and  $c$  are the sides of a triangle,

$$A = \sqrt{s(s-a)(s-b)(s-c)}$$

where  $s = \frac{a+b+c}{2} \quad \dots(18.2)$

(b) **Rectangle:** If  $b$  and ' $d$ ' are the dimension of a rectangle,

$$A = bd \quad \dots(18.3)$$

(c) **Trapezium:**

$A = d \frac{h_1 + h_2}{2}$ , where  $d$  is the distance between two parallel sides and  $h_1$  and  $h_2$  lengths of parallel sides. ... (18.4)

### 18.1.2 Areas of Irregular Shapes

For this purpose from a survey line offsets are taken at regular intervals and area is calculated from any one of the following methods:

(a) Area by Trapezoidal rule

(b) Area by Simpson's rule.

(a) **Area by Trapezoidal Rule:**

If there are ' $n + 1$ ' ordinates at  $n$  equal distances ' $d$ ', then total length of line is  $L = nd$ , Area of each segment is calculated treating it as a trapezium. Referring to Fig. 18.2,

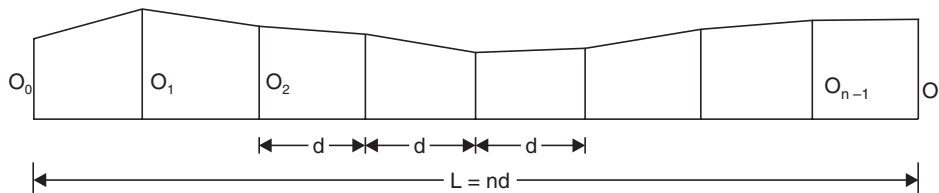


Fig. 18.2

$$\text{Area of first segment} = \frac{O_0 + O_1}{2} d$$

By adding all such segmental areas, we get total

$$\begin{aligned}
 A &= \frac{O_0 + O_1}{2} d + \frac{O_1 + O_2}{2} d + \dots + \frac{O_{n-1} + O_n}{2} d \\
 &= \left[ \frac{O_0 + O_n}{2} + O_1 + O_2 + \dots + O_{n-1} \right] d \quad \dots(18.5)
 \end{aligned}$$

**(b) Area by Simpson's Rule**

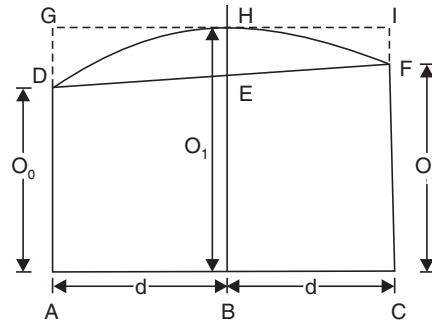


Fig. 18.3

In this method, the boundary line between two segment is assumed parabolic. Figure 18.3 shows the first two segments of Fig. 18.2, in which boundary between the ordinates is assumed parabolic.

∴ Area of the first two segments

$$\begin{aligned}
 &= \text{Area of trapezium ACFD} + \text{Area of parabola DEFH} \\
 &= \frac{O_0 + O_2}{2} 2d + \frac{2}{3} \times 2d \times EH \\
 &= (O_0 + O_2) d + \frac{4}{3} d \left( O_1 - \frac{O_0 + O_2}{2} \right) \\
 &= \frac{d}{3} [3O_0 + 3O_2 + 4O_1 - 2O_0 - 2O_2] \\
 &= \frac{d}{3} [O_0 + 4O_1 + O_2]
 \end{aligned}$$

Area of next two segments

$$= \frac{d}{3} [O_2 + 4O_3 + O_4]$$

Area of last two segments

$$= \frac{d}{3} [O_{n-2} + 4O_{n-1} + O_n]$$

$$\begin{aligned}
 \therefore \text{ Total } \quad A &= \frac{d}{3} \left[ (O_0 + O_n) + 4(O_1 + O_3 + \dots + O_{n-1}) \right. \\
 &\quad \left. + 2(O_2 + O_4 + \dots + O_{n-2}) \right] \quad \dots(18.6)
 \end{aligned}$$

It is to be noted that the equation 18.6 is applicable if the number of segments ( $n$ ) are even, in other words, if total number of ordinates's are odd.

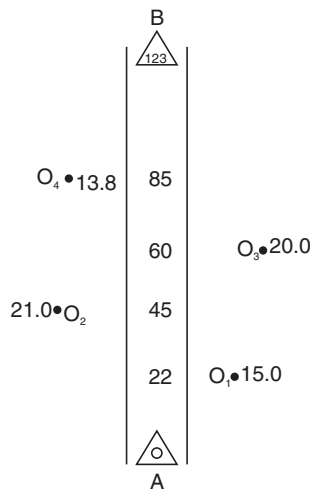


If  $n$  is odd, then for  $n - 1$  segments area is calculated by Simpson's rule and for the last segment trapezoidal rule is applied.

Trapezoidal rule gives better results if the boundary is not irregular to great extent. Simpson's rule should be used if the boundary is highly irregular. This rule gives slightly more value compared to trapezoidal rule, if the curve is concave towards the survey line and gives lesser value, if the boundary is convex towards survey line.

In both methods accuracy can be improved if the number of segments are increased.

■ **Example 18.1:** Plot the following cross staff survey of a land and compute the area:



**Solution:** Referring to Fig. 18.4,

$$\begin{aligned} \text{Total area} = & \text{Area of } \Delta AO_1 C_1 + \text{Area of triangle } AC_2 O_2 + \text{Area of trapezium } C_1 O_1 O_3 C_3 \\ & + \text{Area of trapezium } C_2 C_4 O_4 O_2 + \text{Area of } \Delta C_3 O_3 B + \text{Area of } \Delta C_4 O_4 B \end{aligned}$$

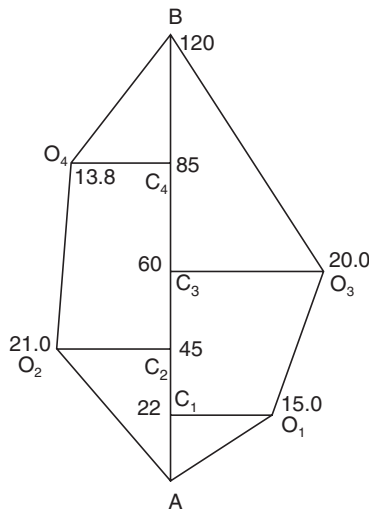


Fig. 18.4

$$= \frac{1}{2} \times 22 \times 15 + \frac{1}{2} \times 45 \times 21 + \frac{1}{2} (15 + 20) (60 - 22) + \frac{1}{2} (13.8 + 21.0) (85 - 45) \\ + \frac{1}{2} \times 20 (120 - 60) + \frac{1}{2} \times 13.8 (120 - 8.5)$$

$$\text{Area} = 2840 \text{ m}^2$$

Ans.

■ **Example 18.2:** The perpendicular offsets taken at 10 m intervals from a survey line to an irregular boundary are 2.18 m, 3.2 m, 4.26 m, 6.2 m, 4.8 m, 7.20 m, 8.8 m, 8.2 m and 5.2 m. Determine the area enclosed between the boundary, survey line, the first and the last offsets by

(i) Trapezoidal rule

(ii) Simpson's rule.

**Solution:**  $d = 10$  m,  $n =$  number of segments = 8 number of ordinates = 9.

Length of survey line =  $8 \times 10 = 80$  m.

(i) Area by trapezoidal rule

$$A = \left( \frac{O_0 + O_8}{2} + O_1 + O_2 + \dots + O_7 \right) d \\ = \left[ \frac{2.18 + 5.2}{2} + 3.2 + 4.26 + 6.2 + 4.8 + 7.2 + 8.8 + 8.2 \right] 10$$

$$\text{Area} = 463.5 \text{ m}^2$$

Ans.

(ii) Area by Simpson's method

$$= \frac{d}{3} [(O_0 + O_8) + 4(O_1 + O_3 + O_5 + O_7) + 2(O_2 + O_4 + O_6)] \\ = \frac{10}{3} [2.18 + 5.2 + 4(3.2 + 6.2 + 7.2 + 8.2) + 2(4.26 + 4.8 + 8.8)] \\ = 474.333 \text{ m}^2$$

Ans.

■ **Example 18.3:** The following offsets were taken to a curved boundary from a survey line:

0, 2.46, 3.78, 3.26, 4.40, 3.28, 4.24 and 5.20 m.

Compute the area between curved boundary, survey line and end offsets, if the offsets were at a regular interval of 10 m, using Simpson's rule and trapezoidal rule. Compare the results.

**Solution:** Number of offsets = 8

Number of intervals = 7

$$O_0 = 0.0, O_1 = 2.40, O_2 = 3.78, O_3 = 3.26, O_4 = 4.40, O_5 = 3.28,$$

$$O_6 = 4.27, O_7 = 5.20$$

$$d = 10.0 \text{ m}$$

(i) From trapezoidal rule

$$A = \left[ \frac{O_0 + O_7}{2} + O_1 + O_2 + O_3 + O_4 + O_5 + O_6 \right] d$$

$$= \left[ \frac{0.0 + 5.20}{2} + 2.46 + 3.78 + 3.26 + 4.40 + 3.28 + 4.27 \right] 10$$

$$= 240.5 \text{ m}^2$$

Ans.

**(ii) Simpson's rule**

Number of intervals are odd (7). Hence for first six intervals Simpson's rule can be applied and for the last interval, trapezoidal rule will be applied.

$$A = \frac{d}{3} [O_0 + O_6 + 4(O_1 + O_3 + O_5) + 2(O_2 + O_4)] + \frac{d}{2} (O_6 + O_7)$$

$$= \frac{10}{3} [0 + 4.27 + 4(2.46 + 3.26 + 3.28) + 2(3.78 + 4.40)] + \frac{10}{2} (4.27 + 5.20)$$

$$= 236.12 \text{ m}^2$$

Ans.

∴ Simpson's rule gave lesser area, the magnitude being  $240.5 - 236.12 = 3.38 \text{ m}^2$  Ans.

## 18.2 COMPUTING AREAS FROM MAPS

If map of an area is available its area can be found by the following methods:

- (i) Approximate methods                      (ii) Using planimeter.

### 18.2.1 Approximate Methods

The following three approximate methods are available for calculating area from the map:

- (a) Give and take method                      (b) Subdivisions into squares  
(c) Subdivisions into rectangles.
- (a) **Give and take method:** In this method irregular boundary is approximated with straight lines such that area taken in is equal to the area given out. Accuracy depends upon the judging capacity of the engineer. Then the area with straight edges is divided into a set of simple figures, like triangles and trapezoids and the area of map is found using standard expressions. Figure 18.5 shows such a scheme.

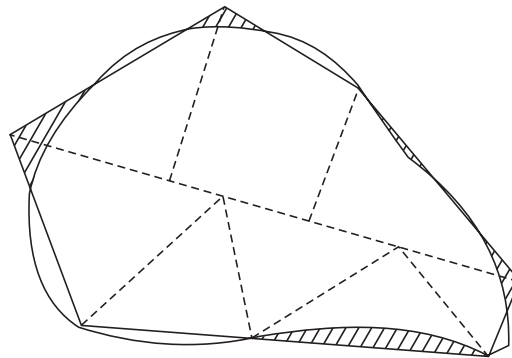


Fig. 18.5

- (b) **Subdivisions into squares:** Similar to a graph sheet, squares are marked on a transparent tracing sheet, each square representing a known area. Full squares are counted. Fractional squares are counted by give and take approximation. Then the number of squares multiplied by area of each square gives the area of the map Fig. 18.6 shows such a scheme. Finer the mesh better is the accuracy.

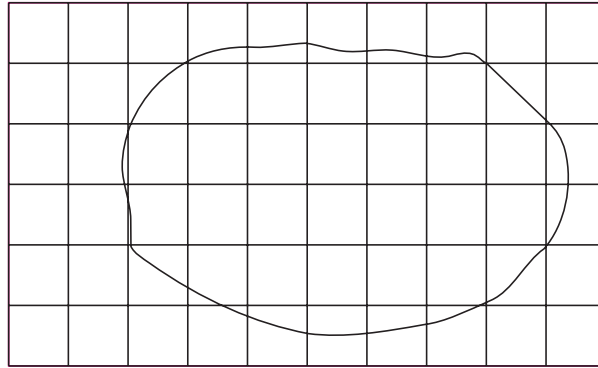


Fig. 18.6

- (c) **Subdivisions into rectangles:** In this method, a set of parallel lines are drawn at equal spacing on a transparent paper. Then that sheet is placed over the map and slightly rotated till two parallel lines touch the edges of the map. Then equalising perpendiculars are drawn between the consecutive parallel line. Thus given area is converted to equivalent set of rectangles and then area is calculated (Ref. Fig. 18.7).

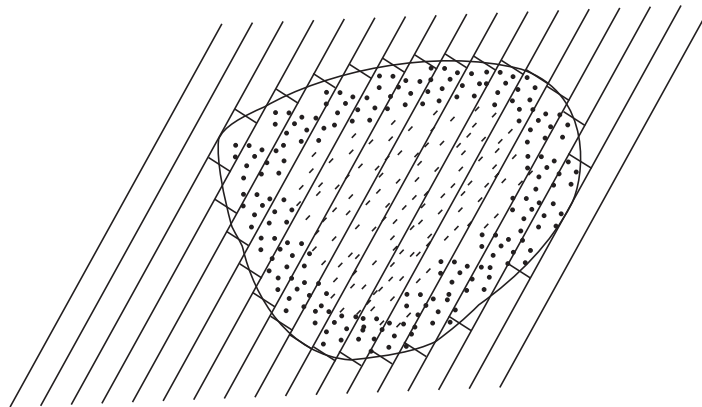


Fig. 18.7

### 18.2.2 Computing Area Using Planimeter

Planimeter is a mechanical instrument used for measuring area of plan. The commonly used planimeter is known as Amsler planimeter (Fig. 18.8). Its construction and uses are explained in this article.

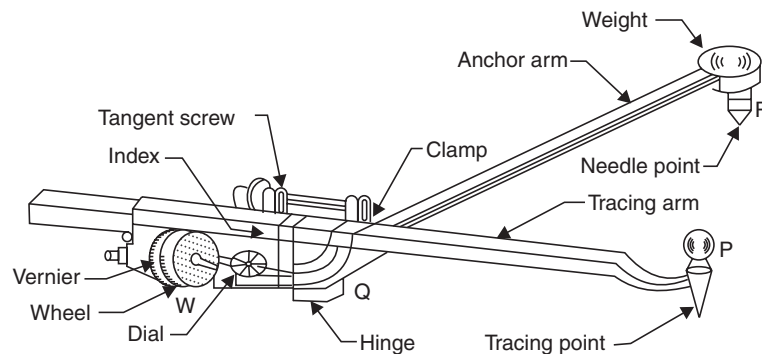


Fig. 18.8. Planimeter

The essential parts of a planimeter are:

1. Anchor: It is a heavy block with a fine anchor pin at its base. It is used to anchor the instrument at a desired point on the plan.
2. Anchor arm: It is a bar with one end attached to anchor block and the other connected to an integrating unit. Its arm length is generally fixed but some planimeters are provided with variable arms length also.
3. Tracing arm: It is a bar carrying a tracer point at one end connected to the integrating unit at the other end. The anchor arm and tracer arms are connected by a hinge. The length of this arm can be varied by means of fixed screw and slow motion screw.
4. Tracing point: This is a needle point connected to the end of tracer arm, which is to be moved over the out line of the area to be measured.
5. Integrating unit: It consists of a hard steel roller and a disc. The axis of roller coincides with the axis of tracer arm hence it rolls only at right angles to the tracer arm. The roller carries a concentric drum which has 100 divisions and is provided with a vernier to read tenth of roller division. A suitable gear system moves a pointer on disc by one division for every one revolution of the roller. Since the disc is provided with 10 such equal divisions, the reading on the integrating unit has four digits:
  - (i) Unit read on the disc
  - (ii) Tenth and hundredth of a unit read on the roller
  - (iii) Thousandth read on the vernier.

Thus if reading on disc is 2, reading on roller is 42 and vernier reads 6, then the total reading

$$F = 2.426$$

### Method of Using Planimeter

To find the area of a plan, anchor point may be placed either outside the plan or inside the plan. It is placed outside the plan, if the plan area is small. Then on the boundary of the plan a point is marked and tracer is set on it. The planimeter reading is taken. After this tracer is carefully moved over the outline of the plan in clockwise direction till the first point is reached. Then the reading is noted. Now the area of the plan may be found as

$$\text{Area} = M (F - I + 10 N + C) \quad \dots(18.7)$$

where

M = A multiplying constant

F = Final reading

I = Initial reading.

N = The number of completed revolutions of disc. Plus sign to be used if the zero mark of the dial passes index mark in clockwise direction and minus sign if it passes in anticlockwise direction.

C = Constant of the instrument, which when multiplied with M, gives the area of zero circle.

**The constant C is added only when the anchor point is inside the area.**

Multiplying constant M is equal to the area of the plan (map) per revolution of the roller *i.e.*, area corresponding to one division of disc.

Multiplying constant M and C are normally written on the planimeter. The user can verify these values by

- (i) Measuring a known area (like that of a rectangle) keeping anchor point outside the area
- (ii) Again measuring a known area by keeping anchor point inside a known area.

The method is explained with example.

The proof of equation 18.7 is considered as beyond the scope of this book. Interested readers can see the book on surveying and levelling.

■ **Example 18.4:** To determine the constants of a planimeter a  $20 \text{ cm} \times 20 \text{ cm}$  area was measured with anchor point outside the plan area. The zero mark of disc crossed the index in clockwise direction once. The observed readings are

$$\text{Initial reading} = 7.422$$

$$\text{Final reading} = 1.422$$

Determine the multiplying constant M.

**Solution:** Area = M (F - I + 10 N)

$$\text{Now} \quad \text{Area} = 20 \times 20 = 400 \text{ cm}^2$$

$$F = 1.422, I = 7.422$$

$$\therefore 400 = M (1.422 - 7.422 + 10 \times 1)$$

$$\therefore \mathbf{M = 100 \text{ cm}^2}$$

**Ans.**

■ **Example 18.5:** A planimeter was used to measure the area of a map once keeping anchor point outside the figure and second time keeping it inside the figure. The observations are as follows:

- (i) When the anchor point was outside the figure:

$$\text{Initial reading} = 1.486$$

$$\text{Final reading} = 7.058$$

The zero of the dial did not pass the index at all.

- (ii) When the anchor point was inside the map:

$$\text{Initial reading} = 3.486$$

$$\text{Final reading} = 8.844$$

Zero mark of the dial passed the fixed index mark twice in anticlockwise direction.

Find the (i) area of the map (ii) area of the zero circle.

Take multiplier constant  $M = 100 \text{ cm}^2$ .

**Solution:** (i) When the anchor point was outside the plan

$$I = 1.486 \quad F = 7.058 \quad N = 0 \quad M = 100 \text{ cm}^2.$$

$$\begin{aligned} \therefore A &= M (F - I + 10 N) \\ &= 100 (7.058 - 1.486 + 0) \end{aligned}$$

$$\therefore A = 557.2 \text{ cm}^2 \quad \text{Ans.}$$

(ii) When the anchor point was inside the plan

$$I = 3.486 \quad F = 8.844 \quad N = -2 \quad M = 100 \text{ cm}^2.$$

$$A = M (F - I + 10 N + C)$$

$$557.2 = 100 (8.844 - 3.486 - 10 \times 2 + C)$$

$$\therefore C = 20.214 \quad \text{Ans.}$$

## 18.3 COMPUTATION OF VOLUMES

The following three methods are available for computation of volumes:

- (i) From cross-sections
- (ii) From spot levels and
- (iii) From contours.

First method is useful for computing earth work involved in road/rail/canal/sewage works. Second method is useful for finding earth work in foundations of large building and the last method is useful for finding capacity of reservoirs.

### 18.3.1 Computation of Volume from Cross-sections

To compute earth work, profile levelling is carried out along the centre line of the alignment of the project and cross-sectional levels are taken at regular intervals. Then the volume of earth work can be found, if the cross-sections are determined.

First the calculation of cross-sectional area is discussed.

(a) If section is level (Fig. 18.9)

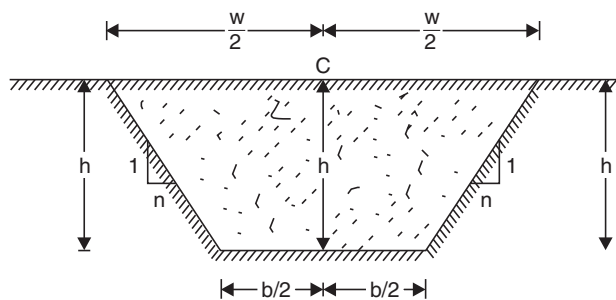


Fig. 18.9

Let 'h' be the depth at the centre line of the alignment and 1 : n be the side slopes. Then

$$w = b + 2nh$$

$$\therefore A = \frac{1}{2} (w + b) h$$

$$= \frac{1}{2} (b + 2nh + b) h$$

$$= (b + nh) h$$

...(18.8)

(b) If it is a multilevel section [Fig. 18.10]

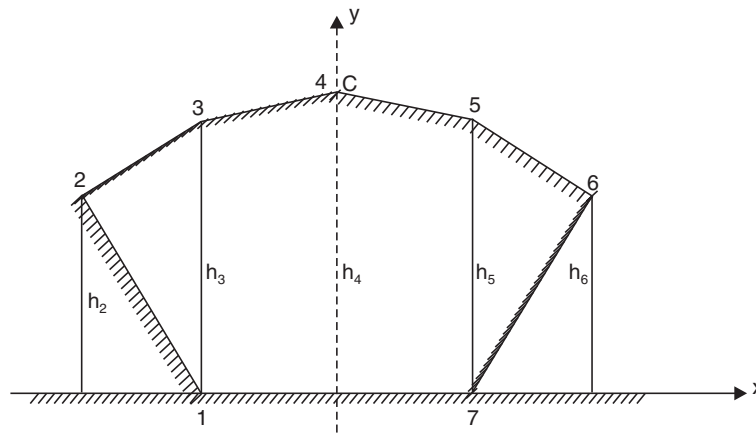
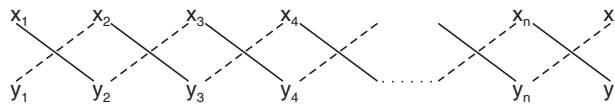


Fig. 18.10

Let the coordinates of points be  $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$ , then arrange the coordinates in the following order



Then area of the figure

$$= \frac{1}{2} [ \Sigma \text{Product of pair of coordinates connected by continuous lines} - \Sigma \text{Product of coordinates connected by dotted lines} ]$$

...(18.9)

The above formula can be easily proved by taking a simple example of a quadrilateral [Ref. Fig. 18.11]. Let the coordinates of A, B, C and D be  $(x_1, y_1), (x_2, y_2), (x_3, y_3)$  and  $(x_4, y_4)$ . Then area of ABCD

$$= \text{Area of } a \text{ AB } b + \text{Area of } b \text{ BC } c + \text{Area of } c \text{ CD } d - \text{Area of } a \text{ AD } d.$$

$$= \frac{1}{2} (x_1 + x_2) (y_2 - y_1) + \frac{1}{2} (x_2 + x_3) (y_3 - y_2) + \frac{1}{2} (x_3 + x_4) (y_4 - y_3) - \frac{1}{2} (x_1 + x_4) (y_4 - y_1)$$



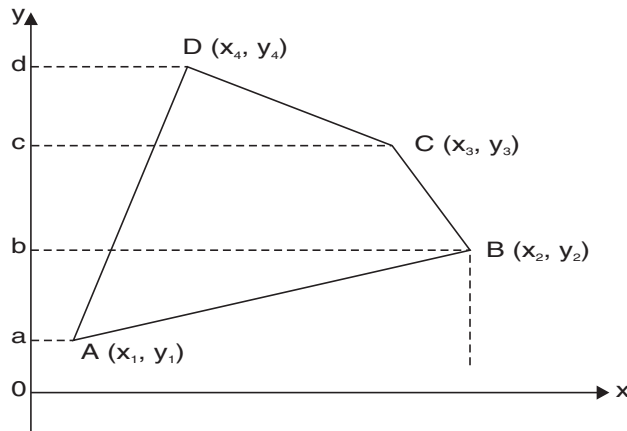


Fig. 18.11

$$\begin{aligned}
 &= \frac{1}{2} [x_1y_2 - x_1y_1 + x_2y_2 - x_2y_1 + x_2y_3 - x_2y_2 + x_3y_3 - x_3y_2 + x_3y_4 - x_3y_3 + x_4y_4 - x_4y_3 \\
 &\qquad\qquad\qquad - x_1y_4 + x_1y_1 - x_4y_4 + x_4y_1] \\
 &= (x_1y_2 + x_2y_3 + x_3y_4 + x_4y_1) - (x_2y_1 + x_3y_2 + x_4y_1 + x_1y_4) \\
 &\text{[Note terms with same subscript appear in pairs and cancell each other].} \\
 &\text{Hence equation 18.9 is proved.}
 \end{aligned}$$

**Calculation of Volumes**

Once cross-sectional areas at various sections are known volume can be found from trapezoidal or prismoidal rule as given below:

**Trapezoidal Rule**

$$V = d \left[ \frac{A_0 + A_n}{2} + A_1 + A_2 + \dots + A_{n-1} \right] \qquad \dots(18.10)$$

where 'n' are number of segments at interval of 'd', Area at L = nd, being A<sub>n</sub>.

**Prismoidal Rule**

$$V = \frac{d}{3} [(A_0 + A_n) + 4(A_1 + A_3 + \dots + A_{n-1}) + 2(A_2 + A_4 + \dots + A_{n-2})] \qquad \dots(18.11)$$

where n is number of even segments.

If number of segments are odd, (n is odd), for n – 1 segments prismoidal rule may be applied and for the last one trapezoidal rule is applied. Or else for the last segment area at middle of last segment found and prismoidal formula applied for A<sub>n-1</sub>, A<sub>m</sub> and A<sub>n</sub>.

■ **Example 18.6:** A railway embankment of formation width 12 m is to be built with side slopes of 1 vertical to 1.5 horizontal. The ground is horizontal in the direction transverse to the centre line. Length of embankment is 200 m. The centre height of embankment at 25 m interval are as given below:

1.6, 2.4, 3.4, 3.8, 4.2, 3.6, 2.8, 2.2, 1.2 m. Calculate the volume of earth filling.

**Solution:** Since the section is level,

$$A = (b + nh) h \text{ where } n = 1.5$$

The area at different sections are:

$$\begin{aligned} A_0 &= (12 + 1.5 \times 1.6) \times 1.6 = 23.04 \text{ m}^2 \\ A_1 &= (12 + 1.5 \times 2.4) \times 2.4 = 37.44 \text{ m}^2 \\ A_2 &= (12 + 1.5 \times 3.4) \times 3.4 = 58.14 \text{ m}^2 \\ A_3 &= (12 + 1.5 \times 3.8) \times 3.8 = 67.26 \text{ m}^2 \\ A_4 &= (12 + 1.5 \times 4.2) \times 4.2 = 76.86 \text{ m}^2 \\ A_5 &= (12 + 1.5 \times 3.6) \times 3.6 = 62.64 \text{ m}^2 \\ A_6 &= (12 + 1.5 \times 2.8) \times 2.8 = 45.36 \text{ m}^2 \\ A_7 &= (12 + 1.5 \times 2.2) \times 2.2 = 33.66 \text{ m}^2 \\ A_8 &= (12 + 1.5 \times 1.2) \times 1.2 = 16.56 \text{ m}^2 \end{aligned}$$

**Volume by Trapezoidal Formula**

$$\begin{aligned} V &= d \left[ \frac{A_0 + A_8}{2} + A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 \right] \\ &= 25 \left[ \frac{23.04 + 16.56}{2} + 37.44 + 58.14 + 67.26 + 76.86 + 62.64 + 45.36 + 33.66 \right] \\ &= 10029 \text{ m}^3 \end{aligned} \quad \text{Ans.}$$

**Volume by Prismoidal Formula**

Since the number of segments are even (8), prismoidal formula

$$\begin{aligned} V &= \frac{d}{3} [A_0 + A_8 + 4(A_1 + A_3 + A_5 + A_7) + 2(A_2 + A_4 + A_6)] \\ &= \frac{25}{3} [23.04 + 16.56 + 4(37.44 + 67.26 + 62.64 + 33.66) + 2(58.14 + 76.86 + 45.36)] \\ &= 10036 \text{ m}^3 \end{aligned} \quad \text{Ans.}$$

■ **Example 18.7:** The following notes refer to a three level work in cutting.

Station			
1	$\frac{2.0}{-7.0}$	$\frac{2.4}{0}$	$\frac{4.8}{11.0}$
2	$\frac{3.0}{-9.0}$	$\frac{3.8}{0}$	$\frac{6.0}{14.0}$

The formation level is in cutting and is 12 m wide. The distance between two points is 40 m. Calculate the volume of cutting between the two stations by

- (i) Trapezoidal formula
- (ii) Prismoidal formula.

**Solution:** The meaning of the notes for station 1 is at centre point *i.e.*, at  $x = 0$ , depth of cutting is 2.4 m, at the end points on left at  $x = 7$  m, the depth of cutting is 2 m and at a point  $x = 11.0$  m depth is 4.8 m as shown in Fig. 18.11. Similarly the meaning for station 2 is also indicated in the Fig. 18.12.

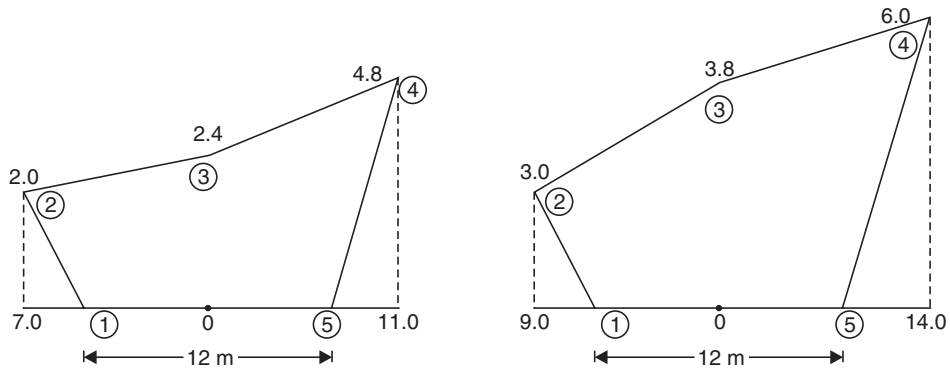


Fig. 18.12

Hence the coordinates of points (1) to (5) on first sections are:

Point →	1	2	3	4	5	1
x	-6.0	-7.0	0	11.0	6.0	-6.0
y	0	2.0	2.4	4.8	0	0

**Note:** Coordinates of first point are written again at the end is the coordinates method of area calculation.

$$\begin{aligned}
 A &= \frac{1}{2} \{[-6 \times 2.0 + (-7.0 \times 2.4) + 0 \times 4.8 + 11.0 \times 0 + 6 \times 0] \\
 &\quad - \{(0.0)(-7.0) + 2 \times 0 + 2.4 \times 11.0 + 4.8 \times 6 + 0 \times (-6)\}\} \\
 &= -42.0 \text{ m}^2 \\
 &= 42.0 \text{ m}^2, \text{ since there is no meaning in -ve sign.}
 \end{aligned}$$

Similarly for section 2,

Point	1	2	3	4	5	1
x	-6.0	-9.0	0	14	6.0	-6
y	0	3.0	3.8	6.0	0	0

$$\begin{aligned}
 \therefore 2A &= \{-6 \times 3.0 - 9.0 \times 3.8 + 0 \times 6 + 14 \times 0 + 6 \times 0\} \\
 &\quad - \{0 \times (-9.0) + 3.0 \times 0 + 3.8 \times 14 + 6 \times 6.0 + 0 \times (-6)\} \\
 &= -141.4 \\
 \therefore A &= 70.7 \text{ m}^2
 \end{aligned}$$

**From Trapezoidal Rule**

$$V = \frac{1}{2} \times 40 (42.0 + 70.7) = 2254.0 \text{ m}^3$$

Ans.

**Prismoidal Rule**

To apply this we need cross-section at middle of the two sections. Assuming uniform slope, it may be found as the points with average coordinates. Hence at mid-section the coordinates of the points are:

Point	1	2	3	4	5	1
x	-6.0	-8.0	0	12.5	6.0	-6
y	0.0	2.5	3.1	5.4	0	0.0

$$\begin{aligned} \therefore 2A_m &= (-6 \times 2.5 - 8 \times 3.1 + 0 \times 5.4 + 12.5 \times 0 + 6 \times 0.0) \\ &\quad - \{0 \times (-8) + 2.5 \times 0 + 3.1 \times 12.5 + 5.4 \times 6.0 + 0 \times (-6)\} \\ &= 110.95 \\ A_m &= 55.475 \text{ m}^2 \end{aligned}$$

Now  $d = \frac{40}{2} = 20 \text{ m}$ , between two consecutive sections.

$$V = \frac{20}{3} (42.0 + 4 \times 55.475 + 70.7)$$

$$V = 2230.67 \text{ m}^3$$

Ans.

### 18.3.2 Computation of Earth Work from Spot Levels

This method is used to calculate volume of earth work for the elevations of basements, large tanks and borrow pits. In this method the whole area is divided into a number of rectangles or triangles (Fig. 18.13). The levels are taken at corner points before and also after excavation. The depth of excavation at each corner point is measured. Then for each simple figure (rectangle or triangle).

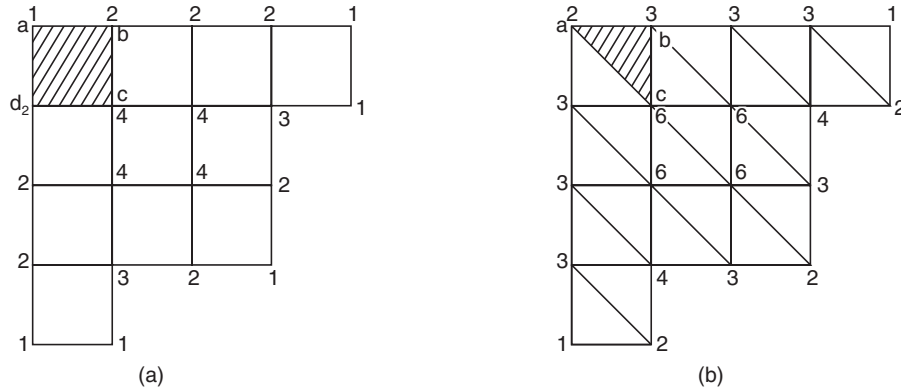


Fig. 18.13

$$V = \text{Area of the figure} \times \text{average depth.}$$

Thus for a rectangle with corner depth  $h_a, h_b, h_c$  and  $h_d$ ,

$$V = \text{Area of rectangle} \times \frac{h_a + h_b + h_c + h_d}{4}$$

For a triangle,

$$V = \text{Area of triangle} \times \frac{h_a + h_b + h_c}{3}$$

All such volumes, when added give total volume of work.

It may be noted that in Fig. 18.13 (a), in total volume calculations depth of some corners appear once, some twice, some of them 3 times and some 4 times. If

- $\Sigma h_1$  = some of depths used once
- $\Sigma h_2$  = sum of depths used twice
- $\Sigma h_3$  = sum of depths used thrice
- $\Sigma h_4$  = sum of depths used four times.

Then

$$V = \frac{A}{4} (\Sigma h_1 + 2\Sigma h_2 + 3\Sigma h_3 + 4\Sigma h_4) \quad \dots(18.12)$$

Similarly in Fig. 18.13 (b), sum depths are used once, some 2 times, some 3 times and some others 6 times. Defining  $h_i$  same as above.

$$V = \frac{A}{3} (\Sigma h_1 + 2\Sigma h_2 + 3\Sigma h_3 + 6\Sigma h_6) \quad \dots(18.13)$$

■ **Example 18.8:** A 60 m × 60 m plot is to be excavated to a formation level of 80.0 m. The present levels at 20 m × 20 m grid are as shown in Fig. 18.14. Calculate the volume of earth work.

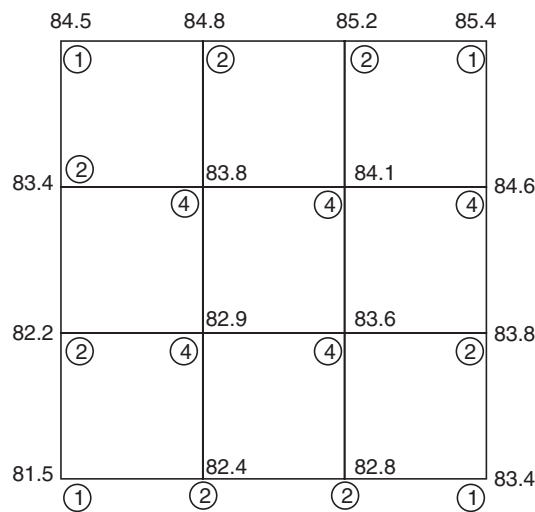


Fig. 18.14

**Solution:** The number of times a particular corner depth is used in volume calculation is marked in circles. Formation level is 80.0 m.

$$\begin{aligned} \therefore \Sigma h_1 &= 4.5 + 5.4 + 3.4 + 1.5 = 14.8 \text{ m} \\ \Sigma h_2 &= 4.8 + 5.2 + 3.4 + 4.6 + 2.2 + 3.8 + 2.4 + 2.8 \\ &= 29.2 \text{ m} \\ \Sigma h_3 &= 0 \\ \Sigma h_4 &= 3.8 + 4.1 + 2.9 + 3.6 = 14.4 \text{ m} \end{aligned}$$

Area of each grid,  $A = 20 \times 20 = 400 \text{ m}^2$ .

$$\begin{aligned} \therefore V &= \frac{400}{4} (14.8 \times 1 + 29.2 \times 2 + 0 \times 3 + 14.4 \times 4) \\ &= 13080 \text{ m}^3. \end{aligned}$$

### 18.3.3 Computation of Volume from Contours

Figure 18.15 shows a dam with full water level of 100 m and contours on upstream side. Capacity of reservoir to be found is nothing but volume of fill with water level at 100 m. The whole area lying within a contour line is found by planimeter. It may be noted that area to be measured is *not* between two consecutive contour lines.

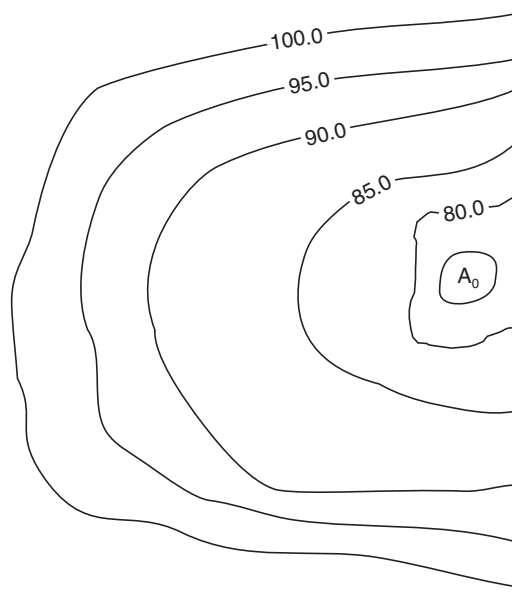


Fig. 18.15

Let  $A_0, A_1, A_2, \dots, A_n$  be area of contours and  $h$  be contour interval. Then from trapezoidal rule:

$$V = h \left[ \frac{A_0 + A_n}{2} + A_1 + A_2 + \dots + A_{n-1} \right]$$

and by prismoidal rule:

$$V = \frac{h}{3} [(A_0 + A_n) + 4(A_1 + A_3 + \dots + A_{n-1}) + 2(A_2 + A_4 + \dots + A_{n-2})]$$

where there are  $n$  segments and  $n$  is even number.

■ **Example 18.9:** The area within the contour lines at the site of reservoir and along the face of the proposed dam are as follows:

Contour	Area in $\text{m}^2$
100 m	800
104 m	9600
108 m	11800
112 m	12400

116 m	14300
120 m	18400
124 m	20360

Assuming 100 m as the bottom level of the reservoir, and 124 m as full level, calculate the capacity of the reservoir using trapezoidal and prismoidal formula.

**Solution: (a) Prismoidal Formula:**

$$\begin{aligned} V &= h \left[ \frac{A_0 + A_n}{2} + A_1 + A_2 + \dots + A_{n-1} \right] \\ &= 4 \left[ \frac{800 + 20360}{2} + 9600 + 11800 + 12400 + 14300 + 18400 \right] \\ &= 308320 \text{ m}^3 \end{aligned}$$

**Ans.**

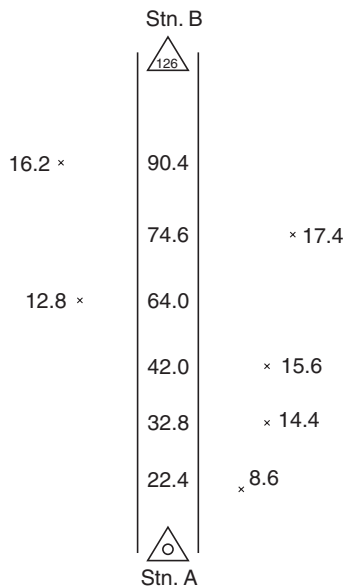
**(b) Prismoidal Formula:**

$$\begin{aligned} V &= \frac{h}{3} [A_0 + A_n + 4(A_1 + A_3 + \dots + A_{n-1}) + 2(A_2 + A_4 + \dots + A_{n-2})] \\ &= \frac{4}{3} [800 + 20360 + 4(9600 + 12400 + 18400) + 2(11800 + 14300)] \\ &= 313280 \text{ m}^3 \end{aligned}$$

**Ans.**

## QUESTIONS

- Find the area of the field from the following notes of cross staff survey, all measurements being in metres.



[Ans: 2419.76 m<sup>2</sup>]

2. The following observations were taken to a boundary from a chain line.

Distance in m	0	10	20	30	40	50	60	70
Offset in m	2.4	3.6	4.2	4.8	4.4	3.8	2.8	1.2

Calculate the area enclosed between the chains line, the boundary line and the end offsets by

- (i) Trapezoidal rule (ii) Simpson's rule **Ans: (i) 254.0 m<sup>2</sup> (ii) 257.33 m<sup>2</sup>**

**[Hint:** Consider first six segment by Simpson's rule and to this add area of last segment found by Trapezoidal rule].

3. A plot of ground is in the form of a quadrilateral. To find the area the following measurements were taken:

$$AB = 118.6 \text{ m} \quad BC = 220.4 \text{ m} \quad CD = 158.4 \text{ m}$$

$$DA = 340.0 \text{ m} \text{ and } AC = 322.0 \text{ m}$$

Find the area of the plot.

**[Ans: 33384.5 m<sup>2</sup>]**

**[Hint:** Divide quadrilateral into two triangles)

4. Describe the planimeter and explain how it is used for finding the area of a given map.  
5. A planimeter was used to measure the area of a map once keeping anchor point outside the figure and second time keeping it inside the figure. The observations are as follows:

- (i) When anchor point was outside the figure:

$$\text{Initial reading} = 7.364$$

$$\text{Final reading} = 3.234$$

The zero of dial passed the index mark once in the clockwise direction.

- (ii) When anchor point was inside the figure:

$$\text{Initial reading} = 2.384$$

$$\text{Final reading} = 4.443$$

The zero of the dial passed the index mark twice in the anticlockwise direction. Take  $M = 100 \text{ cm}^2$ .

**[Ans: Area of zero circle = 2381.1 cm<sup>2</sup>]**

6. How do you determine the multiplying constant and area of zero circle of a planimeter experimentally?  
7. The following are the cross-sectional areas of an embankment at 30 m interval

Distance in m	0	30	60	90	120	150	180
Area in m <sup>2</sup>	122	432	612	720	718	1020	1040

Determine the volume of earth work by (i) trapezoidal formula (ii) prismoidal formula

**[Ans: Trapezoidal formula,  $V = 122490 \text{ m}^3$ , Prismoidal Formula,  $V = 125100 \text{ m}^3$ ]**

8. The areas within the contour lines at the site of a reservoir and along the proposed dam site are as follows:

Contour in m	100	105	110	115	120	125	130
Area in m <sup>2</sup>	1250	1420	17300	20200	25200	32400	36780

Assuming 100 m as bottom level of the reservoir and 130 m as full level, determine the capacity of the reservoir using trapezoidal and prismoidal rules.

**[Ans: Trapezoidal rule,  $V = 578675 \text{ m}^3$ , Prismoidal rule,  $V_2 = 565850 \text{ m}^3$ ]**



## Remote Sensing and Its Applications

Remote sensing is a revolutionary change in surveying in which objects on the earth are sensed from remote places like aircrafts or satellites and are used in map making. It always goes with Geographical Information System (GIS) which is a software tool used for the analysis of remotely sensed data with the help of the computers.

In this chapter introduction is given to remote sensing and GIS. Application of remote sensing is explained.

### 19.1 REMOTE SENSING

Remote sensing may be defined as art and science of collecting informations about objects, area or phenomenon without having physical contact with it. Eye sight and photographs are common examples of remote sensing in which sunlight or artificial light energy from electricity is made to strike the object. Light energy consists of electromagnetic waves of all length and intensity. When electromagnetic wave falls on the object, it is partly

1. absorbed
2. scattered
3. transmitted
4. reflected.

Different objects have different properties of absorbing, scattering, transmitting and reflecting the energy. By capturing reflected waves with sensors, it is possible to identify the objects. However this remote sensing has its own limitations in terms of distance and coverage of area at a time. Photographic survey, in which photographs taken from aircrafts are used for map making, fall under this category of remote sensing. Using electronic equipments, this basic remote sensing technique is extended to identifying and quantifying various objects on the earth by observing them from longer distances from the space. For this purpose, geostationary satellites are launched in the space, which rotate around the earth at the same speed as earth. Hence the relative velocity is zero and they appear stationary when observed from any point on the earth. Depending upon the property of the object, the electromagnetic waves sent from the satellite reflected energy is different. The reflected waves in the bandwidth of infrared, thermal infrared and micro waves are picked up by sensors mounted on satellite. Since each feature on the earth has different reflection property, it is possible to identify the features on

the earth with satellite pictures. Data obtained from satellites are transferred to ground stations through RADARS where user analyses to find out the type of object and the extent of it. This is called image processing. For quantifying the objects computers are used. India is having its own remote sensing satellites like IRS-series, INSAT series and PSLV series.

### Application of Remote Sensing

Various applications of remote sensing may be grouped into the following:

- |                                     |                           |
|-------------------------------------|---------------------------|
| 1. Resource exploration             | 2. Environmental study    |
| 3. Land use                         | 4. Site investigation     |
| 5. Archaeological investigation and | 6. Natural hazards study. |

1. *Resource Exploration*: Geologists use remote sensing to study the formation of sedimentary rocks and identify deposits of various minerals, detect oil fields and identify underground storage of water. Remote sensing is used for identifying potential fishing zone, coral reef mapping and to find other wealth from ocean.

2. *Environmental Study*: Remote sensing is used to study cloud motion and predict rains. With satellite data it is possible to study water discharge from various industries to find out dispersion and harmful effects, if any, on living animals. Oil spillage and oil slicks can be studied using remote sensing.

3. *Land Use*: By remote sensing, mapping of larger areas is possible in short time. Forest area, agricultural area, residential and industrial area can be measured regularly and monitored. It is possible to find out areas of different crops.

4. *Site Investigation*: Remote sensing is used extensively in site investigations for dams, bridges, pipelines. It can be used to locate construction materials like sand and gravel for the new projects.

5. *Archaeological Investigation*: Many structures of old era are now buried under the ground and are not known. But by studying changes in moisture content and other characteristics of the buried objects and upper new layer, remote sensors are able to recognise the buried structures of archaeological importance.

6. *Natural Hazard Study*: Using remote sensing the following natural hazards can be predicted to some extent and hazards minimised:

- |                            |               |
|----------------------------|---------------|
| 1. Earthquake              | 2. Volcanoes  |
| 3. Landslides              | 4. Floods and |
| 5. Hurricane and cyclones. |               |

## 19.2 GEOGRAPHICAL INFORMATION SYSTEM (GIS)

Maps are used as the languages of simple geography. Importance of map making is recognised long ago. Surveyors went round the land and prepared maps. Data required for locating and calculating extent of a place/region is called spatial data.

Physical properties and human activities related to a place/region are stored in the form of tables, charts and texts. This information is called attribute data.

Referring to maps/plans and then to attribute data stored in hard copies like books is time consuming updating and managing the data is difficult.

This problem is overcome by combining spatial data and attribute data of the location by appropriate data base management in computers. The location information (spatial data) is digitised from available maps and stored in computers. For this data structure used is either raster data or vector data format. In raster data structures pickcells are associated with the spatial information, while in vector data structure coordinates are associated with each region and sub-regions. Over the spatial data attribute data is overlaid and stored. Once this geographical information system is developed, the user can access the attribute data of any place by clicking over the spatial data of that place. The user can utilise the information for further analysis, planning or for the management. For example, if land records of a village is developed as GIS data, the user can click the state map to pick up the district map and then access taluka map. Then he will access it to pick up the village map. Then land record of that village can be obtained and property map of any owner can be checked and printed. All this can be achieved in a very short time from any convenient place.

Remote sensing and GIS go hand in hand, since lot of data for GIS is from remote sensing. Remote sensing needs GIS for data analysis. Some of the areas of GIS application are:

- |   |  |
|---|--|
| 1. drainage systems   | 2. streams and river basins management |
| 3. lakes  | 4. canals                              |
| 5. roads  | 6. railways                            |
| 7. land records   | 8. layout of residential areas         |
| 9. location of market, industrial, cultural and other utilities |  |
| 10. land use of different crops etc.                            |  |

The above information helps in planning infrastructural development activities such as planning roads, rail routes, dams, canals, tunnels, etc. It helps in taking steps to check hazards of soil erosion and environmental pollution. Monitoring of crop pattern and condition helps in taking necessary action to the challenges in future.

## QUESTIONS

- Write short notes on
  - Remote sensing
  - Geographical Information System.
- List various area of application of remote sensing.

# **UNIT - V**

## **DISASTER RESISTANT BUILDING**

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## Disaster Resistant Buildings

Disaster means occurrence of uncontrolled, painful and serious conditions. There are various natural disasters like:

- Earthquakes
- Volcanic eruptions
- Cyclones
- Fire
- Landsliding
- Tsunami (a long high sea wave generated by an earthquake)
- Flood.

Earthquakes, cyclone and fire needs special considerations in building design and construction since they are more frequent, widespread and more disastrous. In this chapter this aspect of building design and constructions are discussed.

### 20.1 EARTHQUAKES RESISTANT BUILDINGS

An earthquake is a sudden, rapid shaking of the earth surface caused by the breaking and shifting of rocks beneath. During earthquake, ground motion occurs in a random fashion in all directions radiating from a point within earth crust, called epicentre. It causes vibrations of structures and induce inertia forces on them. As a result structure may collapse resulting into loss of property and lives. Earthquakes do not kill people, vulnerable buildings do so. Hence there is need of designing earthquake resistant buildings, especially in the earthquake prone areas.

### 20.2 TYPES OF EARTHQUAKES

Depending upon the possible causes, the earthquakes may be classified as:

1. Natural earthquake
2. Earthquakes due to induced activities.

### Natural Earthquakes

Natural earthquakes may be due to

- (i) active faults
- (ii) movement of tectonic plates or
- (iii) due to volcanic eruptions.

In earth's crust there are some faults which are not yet settled. The displacement of rocks along faults cause earthquake.

Tectonic means large scale process affecting the structure of the earthcrust. This process causes gradual movement of material within the crust of earth. Sometimes it shakes the earth crust.

Volcano is a mountain or hill having a crater through which lava, rock fragments, hot vapour and gas are or have been erupted from the earths crust. Occasionally the volcanoes become active and create earthquake near the mountain crater.

### Earthquakes due to Induced Activities

These are caused by vibrations induced by atomic explosions and collapse of ground due to faulty mining.

## 20.3 TERMINOLOGY

1. Focus: The point on the fault where slip starts is the focus. It is also known as hypocentre [Ref. Fig. 20.1].
2. Epicentre: The point vertically above the focus on the surface of the earth is the epicentre.
3. Focal Depth: The depth of focus from the epicentre is called the focal depth.
4. Epicentral Distance: Distance from epicentre to any point of interest on the surface of earth is called epicentral distance.

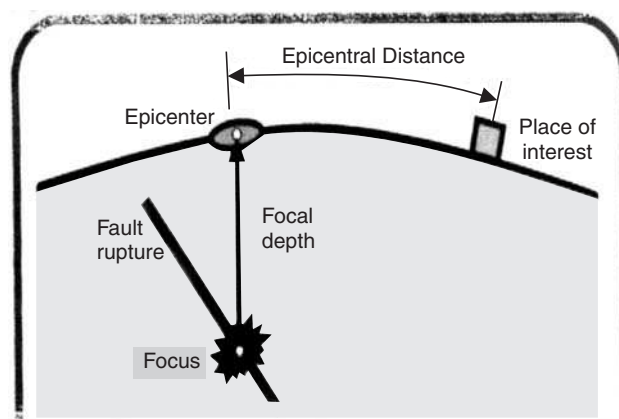


Fig. 20.1

## 20.4 MAGNITUDE AND INTENSITY

*Magnitude* is a quantitative measure of the actual size of the earthquake. Professor Charles Richter proposed the scale of magnitude that goes from 0 to 9. It is a geometric scale. Now this scale is known as Richter scale. It is obtained from the seismograph. It depends on waveform amplitude on epicentral distance. It is denoted by letter M followed by the number. An increase in magnitude by 1 implies 10 times higher waveform amplitude and about 31 times higher energy released. Thus energy released in  $M_6$  and  $M_5$  earthquake have the ratio 31, and  $M_8$  to  $M_5$  have the ratio  $31 \times 31 \times 31$ . There are other magnitude scales, like the Body Wave Magnitude, Surface Wave Magnitude and Wave Energy Magnitude.

Intensity is a qualitative measure of the actual shaking at a location during an earthquake. Hence for the same earthquake, it has different values at different places, highest value being at epicentre. This is a linear scale. It is assigned as Roman Capital Numbers from I to XII.

Intensity depends upon

1. Amount of source energy released
2. Distance between the source and the place of interest
3. Geographical features of the media of travel and importantly on the type of structure.

Modified Mercalli Intensity (MMI) scale is commonly used to express the intensity. MMI scale is as given below:

- I. Very slight, felt only by instruments
- II. Felt by people resting
- III. Felt by passing traffic
- IV. Furnitures and windows rattle
- V. Can be felt outdoors, clocks stop, doors swing
- VI. Furnitures move about, cracks appear in walls
- VII. People knocked over, masonry cracks and falls
- VIII. Chimneys and monuments fall, buildings move on foundations
- IX. Heavy damage to buildings, large cracks open on ground
- X. Most buildings destroyed, landslides occur, water thrown out of lakes
- XI. Catastrophic, railway lines badly bent
- XII. Utter catastrophic, no building is left standing.

Koyna, Great Assam, Bihar and Shillong, Kashmir earthquakes had magnitude 8. Uttarakhand, Chamoli, Jabalpur, Latur, Gujarat approached levels 5.5 to 6.5.

## 20.5 SEISMOGRAPH

Seismograph is an instrument for measuring oscillation of earth during earthquakes. It has three major components—the sensor, the recorder and the timer. Figure 20.2 shows a typical seismograph. The pendulum mass, string, magnet and support together constitute the sensor. The drum, pen and chart paper constitute the recorder. The motor that rotates the drum at constant speed forms the timer. The pen attached to the tip of an oscillating simple pendulum marks on the chart paper. The magnet around the string provides the required damping to control the amplitude of the oscillation.



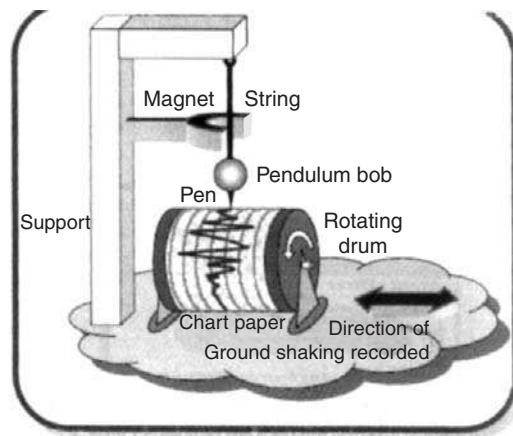


Fig. 20.2. Seismograph

A pair of such oscilloscopes are placed at right angles to each other on a horizontal platform. For measuring vertical oscillations, the string pendulum is replaced with a spring pendulum, oscillating about a fulcrum. Thus three oscilloscopes are installed at each station to measure the oscillations in three mutually perpendicular directions.

Now a days analog instruments are giving way to digital instruments to record the ground motion and process it with microprocessors.

## 20.6 I.S: CODES ON EARTHQUAKE RESISTANT BUILDING DESIGN

After observing Indian earthquakes for several years Bureau of Indian Standard has divided the country into five zones depending upon the severity of earthquake. IS 1893-1984 shows the various zones. The following IS codes will be of great importance for the design engineers:

IS 1893–2002: Criteria for Earthquake Resistant Design of Structures (5th revision).

IS 4928–1993: Code of practice for Earthquake Resistant Design and Construction of Buildings. (2nd revision).

IS 13827–1992: Guidelines for Improving Earthquake Resistance of Low Strength Masonary Building.

IS: 13920–1997: Code of practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces.

IS: 13935–1993: Guidelines for Repair and Seismic Strengthening of Buildings.

## 20.7 IMPROVING EARTHQUAKE RESISTANCE OF SMALL BUILDINGS

The earthquake resistance of small buildings may be increased by taking some precautions and measures in site selections, building planning and constructions as explained below:

- 1. Site Selection:** The building constructions should be avoided on
  - (a) Near unstable embankments
  - (b) On sloping ground with columns of different heights
  - (c) Flood affected areas
  - (d) On subsoil with marked discontinuity like rock in some portion and soil in some portion.
- 2. Building Planning:** Symmetric plans are safer compared to unsymmetric. Hence go for square or rectangular plans rather than L, E, H, T shaped. Rectangular plans should not have length more than twice the width.
- 3. Foundations:** Width of foundation should not be less than 750 mm for single storey building and not less than 900 mm for storeyed buildings. Depth of foundation should not be less than 1.0 m for soft soil and 0.45 m for rocky ground. Before foundation is laid remove all loose materials including water from the trench and compact the bottom. After foundation is laid back-fill the foundation properly and compact.
- 4. Masonry:** *In case of stone masonry:*
  - Place each stone flat on its broadest face.
  - Place length of stones into the thickness of wall to ensure interlocking inside and outside faces of the wall.
  - Fill the voids using small chips of the stones with minimum possible mortar.
  - Break the stone to make it angular so that it has no rounded face.
  - At every 600 to 750 mm distance use through stones.*In case of brick masonry:*
  - Use properly burnt bricks only.
  - Place bricks with its groove mark facing up to ensure better bond with next course.*In case of concrete blocks:*
  - Place rough faces towards top and bottom to get good bond.
  - Blocks should be strong.
  - Brush the top and bottom faces before laying.

In general walls of more than 450 mm should be avoided. Length of wall should be restricted to 6 m. Cross walls make the masonry stronger. It is better to build partition walls along main walls interlinking the two.
- 5. Doors and Window Openings:**
  - Walls with too many doors and windows close to each other collapse early.
  - Windows should be kept at same level.
  - The total width of all openings in wall should not exceed  $\frac{1}{3}$ rd the length of wall.
  - Doors should not be placed at the end of the wall. They should be at least at 500 mm from the cross wall.
  - Clear width between two openings should not be less than 600 mm.

**6. Roof:**

- In sloping roofs with span greater than 6 m use trusses instead of rafters.
- Building with 4 sided sloping roof is stronger than the one with two sided sloping, since gable walls collapse early.

**7. Chejjas:**

- Restrict chejja or balcony projections to 0.9 m. For larger projections use beams and columns.

**8. Parapet:** Masonry parapet wall can collapse easily. It is better to build parapet with bricks up to 300 mm followed by iron railings.

**9. Concrete and Mortar:** Use river sand for making mortar and concrete. It should be sieved to remove pebbles. Silt should be removed by holding it against wind. Coarse aggregates of size more than 30 mm should not be used. Aggregates should be well graded and angular. Before adding water cement and aggregates should be dry mixed thoroughly.

**10. Bands:** The following R.C. bands should be provided

- (a) Plinth band
- (b) Lintel band
- (c) Roof band
- (d) Gable band.

For making R.C. bands minimum thickness is 75 mm and at least two bars of 8 mm diameters are required. They should be tied with steel limbs of 6 mm diameter at 150 mm spacing.

If wall size is large, diagonal and vertical bands also may be provided.

**11. Retrofitting:** Retrofitting means preparing a structure in a scientific manner so that all elements of a building act as an integral unit.

It is generally the most economical and fastest way to achieve safety of the building. The following are some of the methods in retrofitting:

- Anchor roof truss to walls with brackets.
- Provide bracings at the level of purlins and bottom chord members of trusses.
- Strengthen gable wall by inserting sloping belt on gable wall.
- Strengthen corners with seismic belts.
- Anchor floor joists to walls with brackets.
- Improve storey connections by providing vertical reinforcement.
- Induce tensile strength against vertical bending of walls by providing vertical reinforcement at all inside and outside corners.
- Encase wall openings with reinforcements.

## 20.8 IMPROVING EARTHQUAKE RESISTANCE OF TALL BUILDINGS

Tall buildings are subjected to heavy horizontal forces due to inertia during earthquake. Hence they need shear walls. A shear wall is a R.C.C. enclosure within the building built to take shear forces. It is

usually built around lift room. These shear walls must be provided evenly throughout the buildings in both directions as well as from bottom to top. Apart from providing shear walls, the following techniques are also used for making tall buildings earthquake resistant:

1. Base Isolation
2. Using Seismic Dampers.

### 20.8.1 Base Isolation

The idea behind base isolation is to detach (isolate) the building from the ground in such a way that earthquake motions are not transmitted up through the building, or at least greatly reduced. The concept of base isolation is explained through an example of building resting on roller [Fig. 20.3]. When the ground shakes, the roller freely roll but the building above does not move. If the gap between the building and the vertical wall of foundation pit is small, the vertical wall of the pit may hit the wall.

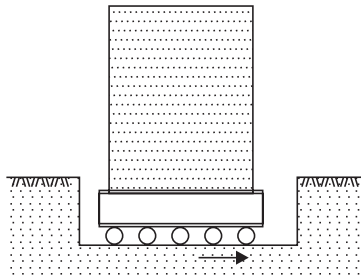


Fig. 20.3. Hypothetical building

Hence 100% frictionless rollers are not provided in practice. The building is rested on flexible pads that offer resistance against lateral movements [Fig. 20.4]. This reduces some effect of ground shaking to the building. The flexible pads are called base-isolators, whereas the structures protected by means of these devices are called base-isolated buildings.

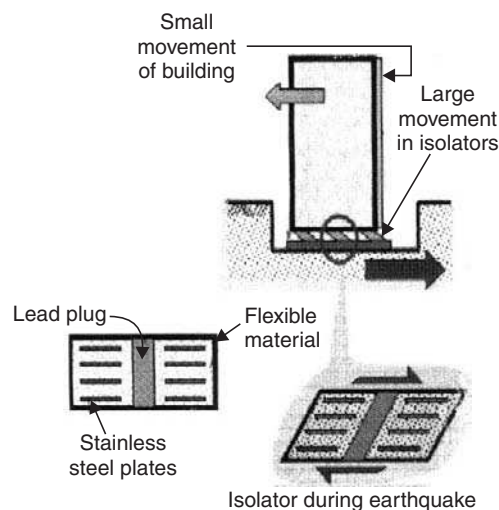


Fig. 20.4. Base isolated building

### 20.8.2 Seismic Dampers

Another approach for controlling seismic damage in buildings is by installing seismic dampers in place of structural elements, such as diagonal braces. When seismic energy is transmitted through them, dampers absorb part of it, and thus damp the motion of the building. Figure 20.4 shows the following types of seismic isolation bearings:

- (a) High density rubber bearings                      (b) Laminated rubber bearings and  
(c) Friction pendulum bearings.

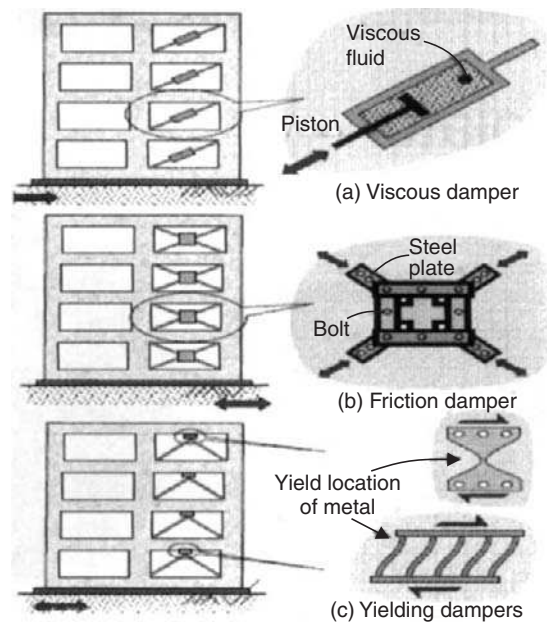


Fig. 20.5. Seismic dampers

## 20.9 CYCLONE RESISTANT BUILDINGS

A cyclone is a storm accompanied by high speed whistling and howling winds. It brings torrential rains. A cyclone storm develops over tropical ocean and blows at speed as high as 200–240 km/hour. It is usually accompanied by lightning, thunder and continuous downpour of rain. Cyclones extend from 150 km to 1200 km in lateral directions with forced winds spiralling around a central low pressure area. The central region of light winds and low pressure, known as the ‘eye’ of cyclone has an average diameter of 20 to 30 km. This central eye is surrounded by a ring of very strong winds extending up to 40 to 50 km beyond centre. This region is called ‘wall cloud’. In this region strongest winds and torrential rains occur. Beyond this region winds spiralling extend outwards to large distances, which goes on reducing with the distance from the centre of the cyclone.

The following care should be taken in designing buildings in cyclone prone areas:

1. Foundations should be deeper
2. R.C.C. framed structures are to be preferred over load bearing structures
3. Sloping roofs should be avoided.

4. Cantilever projections should be avoided.
5. Roof and parapet wall should be properly anchored to the columns and walls.
6. Height of the buildings should be restricted.
7. Suitable wind load should be considered in the building design.
8. Openings in the wall should be less.
9. Structure should not rest on loose soil.

## 20.10 FIRE RESISTANT BUILDING

It is reported that in USA fire kills more people each year than all other natural disasters combined including floods, cyclones and earthquake. The **fire load** in a building should be kept to the minimum possible. The term fire load indicates the amount of heat liberated in kilo joules per square metre ( $\text{kJ/m}^2$ ) of floor area of any compartment by the combustion of the content of the building including its own combustible part. It is determined by multiplying the weights of all combustible materials by their respective calorific values and dividing that with floor area.

A building may be made more fire resistant by

1. Using suitable materials
2. Taking precautions in building construction
3. By providing fire alarm systems and fire extinguishers.

### 20.10.1 Using Suitable Materials

The fire resisting material is having the following characters:

- (a) It should not disintegrate under the effect of heat
- (b) It should not expand under heat so as to introduce unnecessary stresses in the building
- (c) The material should not catch fire easily
- (d) It should not lose its strength when subjected to fire.

Fire resisting characters of some of the commonly used building materials are given below:

**Stone:** It is a bad conductor of heat. Sand stones with fire grains can resist fire moderately. Granite disintegrate under fire. Lime stone crumbles easily. Most of the stones disintegrate during cooling period after heated by fire.

**Brick:** Bricks can resist heat up to  $1200^\circ\text{C}$ . At the time of construction, if good quality mortar is used, fire resistance is extremely good.

**Timber:** Any structure made of timbers is rapidly destroyed in fire. Timber enhances the intensity of fire. Use of heavy sections of timber in buildings is not desirable. To make timber more fire resistant the surface of timber is coated with chemicals such as ammonium phosphate and sulphate, boric acid and borax. Sometimes fire resistant paint is applied to timber used in the building.

**Concrete:** Concrete has got very good fire resistance. The actual behaviour of concrete in case of fire depends upon the quality of cement and aggregates used. In case of reinforced concrete and prestressed concrete, it also depends upon the position of steel. Larger the concrete cover, better is the fire resistance of the member.

There is no loss in strength in concrete when it is heated up to 250°C. The reduction in strength starts if the temperature goes beyond 250°C. Normally reinforced concrete structures can resist fire for about one hour at a temperature of 1000°C. Hence cement concrete is ideally used fire resistant material.

**Steel:** It is a good conductor of heat. Steel bars lose tensile strength. Steel yields at 600°C. They melt at 1400°C. Steel columns become unsafe during fire. Steel reinforcement weakens the reinforced concrete structures. Hence steel columns are usually protected with brick works or by encasing in concrete. Reinforcement in concrete is protected by concrete cover. Steel girders and beams are applied with fire resistant paints.

**Glass:** It is a poor conductor of heat. It expands little during heating. After heating when it cools, cracks are formed in glass. Reinforced glass with steel wire is more resistant to fire and during cooling process, even if it breaks, fractured glasses are in their original position.

**Aluminium:** It is good conductor of heat. It has got higher resistance to fire.

**Asbestos Cement:** It is non-combustible material. It possesses high fire resistance.

### 20.10.2 Fire Protection by Taking Precautions in Building Construction

A building may be made more fire resistant by minimizing use of combustible materials, protecting steel by fire resistant paints and providing stairs at suitable positions and protecting them from fire. Various members of buildings can be made fire resistant as follows:

**Walls:** Brick walls with cement plaster gives better fire resistance.

**Roof:** R.C.C. flat roofs have good fire resistance. Hence they should be preferred.

**Ceiling:** Ceilings should be made up of cement plaster, asbestos cement board or fibre boards.

**Floors:** R.C.C. floor is very good fire resisting floor.

**Doors and Window Openings:** All these openings should be protected against fire by taking the following precautions:

(a) The thickness of shutters should not be less than 40 mm.

(b) Instead of wooden, aluminium or steel shutters should be preferred.

(c) They should be provided with fire proof paints.

**Stairs:** Wood should be avoided in the stair cases. To minimize fire hazard, stairs should be centrally placed in the buildings so that people can approach them quickly. More than one stair case is always preferable. Emergency ladder should be provided in the building.

**Structural Design:** It should be such that under worst situation, even if part of the structure collapses, it should be localised and alternate routes are available for escape.

### 20.10.3 Fire Alarm System and Fire Extinguishers

All important buildings should be provided with fire alarm system. Alarm may be manual or automatic. Automatic alarm sense the smoke and activate bells.

Fire extinguishers should be provided at all strategic points in the buildings. The common fire extinguishers are as follows:

- (a) Manual: Carbon dioxide type portable fire extinguishers are commonly used. Sometimes buckets of water, sand and asbestos blankets are kept ready at all possible places where fire is likely to catch.
- (b) Internal Hydrant: The hydrant should be located in and around the buildings so that water is available easily for fire fighting.
- (c) Automatic Water Sprinkler: In the buildings vulnerable for fire like textile mills, paper mills automatic water sprinklers are installed. As the fire takes place the sprinkling of water is automatically activated from the piping system containing water under pressure.

## QUESTIONS

1. What do you understand by the term earthquakes? What are its causes? State different types of earthquake.
2. Define and explain the following terms with a neat sketch:
  - (a) Focus
  - (b) Epicentre
  - (c) Focal length and
  - (d) Epicentral distance of earthquake.
3. Write short notes on
  - (a) Magnitude
  - (b) Intensity of earthquake and
  - (c) Seismograph.
4. Describe the various provisions to be made to make a medium size building earthquake resistant.
5. Explain the different bands to be given in a building to make it earthquake resistant.
6. Write short notes on
  - (a) Base isolators
  - (b) Seismic dampers.
7. What special cares are to be taken to make buildings cyclone resistant?
9. Write short note on cyclones.
10. Describe the characteristics of an ideal fire proofing material and discuss fire resistant properties of any four building materials.
11. How a building can be made fire resistant? Describe in short.
12. Write short notes on
  - (a) Fire alarm system
  - (b) Fire extinguishers
  - (c) Fire load.



## Disaster Management and Planning

Disaster is a natural calamity which may be in the form of

- Drought
- Flood
- Cyclone
- Forest fire
- Landslide
- Earthquake
- Volcanic eruption etc.

India is one of the most vulnerable developing countries because of the following reasons:

- Unstable land form
- High density of population
- Poverty
- Illiteracy and
- Lack of adequate infrastructure.

In India about 60 per cent land mass is prone to earthquake. Over 40 million hectare is prone to floods. 8 per cent is prone to cyclone and 68 per cent is susceptible to drought. From 1990–2000 on an average every year 4344 people lost their lives and 30 million people were affected by disaster. Hence there is need to adopt a multidimensional approach involving diverse scientific, engineering, financial and social processes. Apart from devastating impact on human life it costs on economy and environment.

In this chapter disaster prevention strategy, early warning system, disaster mitigation and protection, disaster rescue and relief, disaster resettlement, rehabilitation, reconstruction and disaster management techniques have been presented.

### 21.1 DISASTER PREVENTION STRATEGY

Construction of dams can prevent flood havoc. Identify the rivers and construct dams to regulate flow of water during heavy rainfalls. Floods in many areas like Punjab, Ganges plateau, Assam and Bengal

have been controlled to a great extent. Spreading the awareness of building earthquake, cyclone and fire resistant structures can prevent disasters. Major and minor irrigation projects aim at controlling drought.

## 21.2 EARLY WARNING SYSTEM

Space technology plays an important role in efficient mitigation of disaster. Indian Meteorological Department has developed a four stage warning system for a cyclone. The system works on the observation of development of low pressures in ocean 48 hours prior to the time of expected cyclone to hit land the alert warning is given. 24 hours prior to the anticipated time of arrival of cyclone, warning is given. Then 12 hours early cyclone arrival warning is given. Warnings about storms, their intensity and the likely path on regularly given through radio and television until the storm passes over.

## 21.3 DISASTER PREPAREDNESS

At all levels of civil administration committees are established and responsibilities and urgently required finance entrusted. At national level Ministry of Home Affairs, Government of India, a national disaster management division is established. It has prepared guidelines for disaster management. The national disaster management authority is responsible for

- Providing necessary support and assistance to state Governments.
- Coordinating and managing Government policies for disaster mitigation.
- Ensure adequate preparedness at all levels.
- Coordinating response to a disaster when it strikes.
- Assisting the provisional Governments in coordinating post disaster relief and rehabilitation.
- Monitor and introduce a culture of building a requisite features of disaster mitigation in all development plan and programmes.

In India all states have been asked to set up Disaster Management Authorities. Chief Minister heads this authority. He is assisted by senior officers from various departments like Water Resources, Agriculture, Water Supply, Environment, Forest, Urban and Rural development.

At district level district magistrate/deputy commissioner heads the committee. He is assisted by the officers from various departments in the district. At block levels also disaster management committees have been established. Every concerned person is informed about his duties and responsibilities in disaster management. The committees have major role in

- Community involvement and awareness generation.
- Close interaction with the corporate sector, Non-Governmental Organisations (NGO) and the media.
- Train the disaster managers.

Training the concerned people in facing national disaster is very important part of disaster preparedness. Training programmes are organised in Administrative Training Institutions and at various places for different target groups. In CBSE curriculum also lessons are added on disaster mitigation.

The masons and engineers should be trained to build earthquake, cyclone and fire resistant buildings. Hospital staff should be trained to take the challenges of disaster management. Disaster prone areas are to be identified and at suitable places good hospitals should be built, communication facility provided including helicopter landings. Sufficient medicines should be stored.

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## 21.4 DISASTER MITIGATION

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Disaster mitigation means minimizing the painfulness which occur due to disaster. After the disaster the people face the following problems:

1. Shelters are completely or partially damaged
2. Food is not available when required
3. Drinking water shortage is felt.
4. Diseases spread.
5. Communication systems are affected.

To mitigate the misery of the affected people the following steps are to be taken:

1. Provide temporary accommodation with water supply, sanitary and electricity facilities.
2. Extend manpower, material and financial assistance to repair/build their houses.
3. During the expected period of cyclones and floods, store up at least seven day stock of essential food articles, medicines and water supply.
4. Continue to listen to warning bulleting and keep in touch with local officials.
5. Be ready to evacuate people to places of safety when advised.
6. Remove damaged and decayed parts of trees to make them resist wind and reduce the potential for damage.
7. Before cyclone season starts carry out all necessary repairs to the building.
8. Keep valuables and documents in containers which cannot be damaged by water.
9. Talk to children and explain about cyclone/flood. Remain calm.
10. Fishermen are advised not to venture into the sea during cyclone warning period.
11. Avoid taking shelter near old and damaged building or near trees.
12. Do not touch power lines.

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## 21.5 DISASTER RESCUE AND RELIEF MEASURES

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Disaster rescue and relief means taking steps to face the distress situation after the disaster has taken place. Volunteer groups, police force or military teams are organised to

- Rescue the people trapped.
- Rendering first aid to wounded
- Donating blood
- Organizing clearing up so that normalcy returns.
- Locating places where dead bodies can be kept until they are disposed off.

The groups should know that victims are demoralized, anxious and depressed. The volunteers have to win the confidence of victims and carry out rescue operations.

The officers carrying out rescue and relief measures should have good leadership qualities and quick decision taking abilities. Emergency announcements should be made. Required rescue teams should be formed and guided. Higher authorities informed about the situation continuously. Mobilize national resources, if necessary. They should undertake steps for compensation and maintenance of rescue operations.

## 21.6 DISASTER RESETTLEMENT, REHABILITATION AND RECONSTRUCTION

Disaster resettlement, rehabilitation and reconstruction means taking steps to mitigate the problems of victims after the disaster disappears.

Victims need help and assistance to return to their homes after disaster period is over. They may be helped to build their damaged houses. If it is flood prone area, they may be provided sites at new settlement areas which are safe. Financial assistance may be mobilized for constructing houses. The new area should be developed by providing approach roads, water supply and electricity.

Loss of lives and crop should be compensated. New settlement should have school and hospital facilities. All efforts should be made to get normalcy restored.

## QUESTIONS

1. Define the term 'disaster'. Name various disasters. List various factors contributing to disaster management problems.
2. Write short notes on
  - (a) Early disaster warning systems
  - (b) Disaster preparedness
  - (c) Disaster mitigation
  - (d) Disaster rescue and relief methods
  - (e) Disaster resettlement, rehabilitation and reconstruction.

## Indian Standard Codes

All major countries like India, USA, UK, Australia are having their own standards for material standards, testing standards, design procedures and for finished products. Before independence, India followed British standards, but after independence it was felt there is need to prepare the standards to meet the Indian environment. Hence Indian Standard Institution was established, which is now known as Bureau of Indian Standards. It has prepared more than 4000 standards and now and then new standard codes are brought out. In this chapter some of the important IS codes for building design and constructions are listed and briefly explained.

### 22.1 IS CODES FOR BUILDING DESIGN

The following codes help engineers to design buildings:

1. IS 456–2000. It is code of practice for the design of plain and reinforced concrete. It was first brought out in 1953. It was revised in 1957, 1984 and the latest revision is in the year 2000. It gives specifications or specifies the other codes for the requirement of various materials used in making concrete. It classifies concrete into various grades based on 28 days concrete cube strength. It specifies the methods and care to be taken in transporting, placing, compacting and using of concrete. It gives general design considerations, special design requirements and gives design procedure for various structural elements by limit state method approach. Both strength and serviceability requirements are to be satisfied in the design.

IS 800–2007: It titled as General Construction in steel-code and practice. To achieve efficient and optimum standards for structural steel products, Indian Standard Institution initiated action in 1950 and was able to bring out a code in 1956. The code was revised in 1962, 1984 and the latest revision is in the year 2007. It gives guidelines for various class of steel, loads to be considered in the design and the method of designing steel members by limit state method. It gives the serviceability requirements to be fulfilled in the design.

IS 875–1984: It is the Indian Code of practice for Design Loads for Building and Structures. It is available in five parts. Specifications are available for taking loads such as dead loads, live loads, wind loads, snow loads, crane loads etc. Dead load depends upon the type of structures and also on the part of

structure. Wind loads and snow loads depend upon the region, location of site, slopes of building roof, height of building etc. The code gives the guidelines for determining these loads on the building to be designed. Code also gives the combination of loads to be considered in the building design.

IS 1343–1980: It is the code of practice for prestressed concrete. It gives guidelines for selecting materials, specifies workmanship, inspection and testing. General design requirements and limit state method for structural design are presented. Requirements for durability are also specified.

IS 1893–2002: It gives criteria for Earthquake Resistant Design of Structures. IS 4928–1993 is the code of practice for Earthquake Resistant Design and Construction of Buildings. IS 13827–1992 gives guidelines for Improving Earthquake Resistance of Low Cost Strength Masonry Buildings.

IS 13920–1997: It is the code of practice for Ductile Detailing of Reinforced concrete structures subjected to Seismic Forces. IS 13935–1993 gives guidelines for Repair and Seismic Strengthening of Buildings.

## 22.2 IS CODES FOR BUILDING MATERIALS AND CONSTRUCTION

The following is the list of some of the IS code giving requirements for building materials:

IS 269–1989. Specification for ordinary portland cement.

IS 455–1989. Specification for portland slag cement.

IS 516–1959. Method of tests for strength of concrete.

IS 1123–1975. Method of identification of natural building stones.

IS 383–1970. Specifications for coarse and fine aggregates.

IS 432–1982. Specification for mild steel.

IS 3495–1976. Gives specifications for building bricks.

IS 287–1973. Gives maximum permissible moisture content in timber for different zone and for different uses.

## QUESTIONS

1. What is IS code ? Discuss their importance.
2. Write the names of any four IS codes used for building design and construction. Briefly describe them.