



### Unit – I

## Building Materials & Construction

### CHAPTER - 1 STONES

#### Introduction:

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.

#### 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.

#### Types of Stones:

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

1. Geological Classification
2. Physical Classification
3. Chemical Classification

#### 1. 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 disintegrates. 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 greisses, trap and basalt change to schist and laterite, lime stone changes to marble, sand stone becomes quartzite and mud stone becomes slate. Physical Classification



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### 2. Physical Classification

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

**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.

### 3. Chemical Classification

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

**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.

**iii) 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.

### 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 N/mm<sup>2</sup> 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



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can hardly give a stress of 0.15 N/mm . 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 N/mm<sup>2</sup></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%.



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(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.

### 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.



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(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.

### 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,

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

$$\text{Percentage absorption by volume} = \frac{W_2 - W_1}{\frac{W_3 - W_1}{3}} \times 100 \quad \dots(2)$$

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

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

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

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

(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.

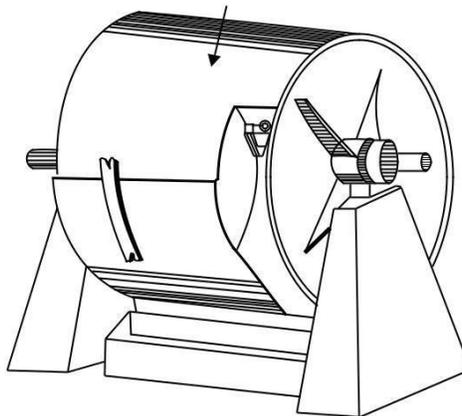


Fig. 1.1. Los Angeles testing machine

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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 1.75 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.

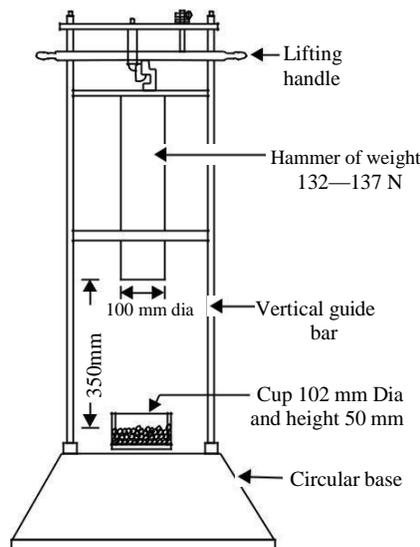


Fig. 1.2. Aggregate impact testing machine

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 = 30%



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- (ii) for bituminous mehadam = 35%
- (iii) for water bound mehadam = 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.

### 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.

### 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 kN/m<sup>3</sup> to 29 kN/m<sup>3</sup>. The compressive strength varies from 200 to 350 N/mm<sup>2</sup>. 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.



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(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/m<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/m<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/m<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.