Catalog

1.1 Characteristics of Good Building Stone

A good building stone should have the following qualities.

1. **Appearance:** For face work it should have fine, compact texture; light-colored stone is preferred as dark colours are likely to fade out in due course of time.
2. **Structure:** A broken stone should not be dull in appearance and should have uniform texture free from cavities, cracks, and patches of loose or soft material. Stratifications should not be visible to naked eye. **Strength:** A stone should be strong and durable to withstand the disintegrating action of weather. Compressive strength of building stones in practice range between 60 to 200 N/mm^2.
3. **Weight:** It is an indication of the porosity and density. For stability of structures such as dams. Retaining walls, etc. heavier stones are required, whereas for arches, vaults, domes, etc. light stones may be the choice.
4. **Hardness:** This property is important for floors, pavements, aprons of bridges, etc. The hardness is determined by the Mohr's scale
5. **Toughness:** The measure of impact that a stone can withstand is defined as toughness. The stone used should be tough when vibratory or moving loads are anticipated.
6. **Porosity and Absorption:** Porosity depends on the mineral constituents, cooling time and structural formation. A porous stone disintegrates as the absorbed rain water freezes, expands, and causes cracking. Permissible water absorption for some of the stones is given in Table 1

Table 1 24-Hours Water Absorption of Stones by Volume

s.no	**Types of Stone**	**Water absorption(% not greater than)**
1.	Sandstone	10
2.	Limestone	10
3.	Granite	1
4.	Trap	6

5.	Shale	10
6.	Gneiss	1
7.	Slate	1
8.	Quartzite	3

7. **Seasoning:** The stone should be well seasoned.
8. **Weathering:** The resistance of stone against the wear and tear due to natural agencies should be high. **Workability:** Stone should be workable so that cutting, dressing and bringing it out in the required shape and size may not be uneconomical.
9. **Fire Resistance:** Stones should be free from calcium carbonate, oxides of iron, and minerals having different coefficients of thermal expansion. Igneous rock show marked disintegration principally because of quartz which disintegrates into small particles at a temperature of about 575°C. Limestone, however, can withstand a little higher temperature; i.e. up to 800°C after which they disintegrate.
10. **Specific Gravity:** The specific gravity of most of the stones lies between 2.3 to 2.5.
11. **Thermal Movement:** Thermal movements alone are usually not trouble-some. However, joints in coping and parapets open-out in letting the rain water causing trouble. Marble slabs show a distinct distortion when subjected to heat. An exposure of one side of marble slab to heat may cause that side to expand and the slab warps. On cooling, the slab does not go back to its original shape.

1.2 Tests on Building Stones

Following are different tests on building stones:

1. Acid test
2. Attrition test
3. Crushing test
4. Crystalline test
5. Freezing and thawing test
6. Hardness Test
7. Impact test
8. Water absorption test
9. Microscopic Test
10. Smith's Test

1. Acid Test on Building Stone

- This test is carried out to understand the presence of calcium carbonate in building stone.
- A sample of stone weighing about 50 to 100 gm is taken.
- It is placed in a solution of hydrophobic acid having strength of one percent and is kept there for seven days. Solution is agitated at intervals.
- A good building stone maintains its sharp edges and keeps its surface free from powder at the end of this period.
- If the edges are broken and powder is formed on the surface, it indicates the presence of calcium carbonate and such a stone will have poor weathering quality.
- This test is usually carried out on sandstones.

2. Attrition Test on Building Stone

This test is done to find out the rate of wear of stones, which are used in road construction. The results of the test indicate the resisting power of stones against the grinding action under traffic. The following procedure is adopted:

- A sample of stones is broken into pieces about 60mm size.
- Such pieces, weighing 5 kg are put in both the cylinders of Devil's attrition test machine. Diameter and length of cylinder are respectively 20 cm and

34 cm.

- Cylinders are closed. Their axes make an angle of 30 degree with the horizontal.
- Cylinders are rotated about the horizontal axis for 5 hours at the rate of 30 rpm.
- After this period, the contents are taken out from the cylinders and they are passed through a sieve of 1.5mm mesh.
- Quality of material which is retained on the sieve is weighed.
- Percentage wear worked out as follows:

  Percentage wear = (Loss in Weight/Initial Weight) x 100

3. Crushing Test on Building Stone

- Samples of stone is cut into cubes of size 40 x 40 x 40 mm sizes of cubes are finely dressed and finished.
- Maximum number of specimen to be tested is three. Such specimen should be placed in water for about 72 hours prior to test and therefore tested in saturated condition.
- Load bearing surface is then covered with plaster of paris of about 5mm thick plywood.
- Load is applied axially on the cube in a crushing test machine. Rate of loading is 140 kg/sq.cm per minute.
- Crushing strength of the stone per unit area is the maximum load at which the sample crushes or fails divided by the area of the bearing face of the specimen.

4. Crystalline Test on Building Stone

- At least four cubes of stone with side as 40mm are taken.
- They are dried for 72 hrs and weighed. They are then immersed in 14% solution of Na2SO4 for 2 hours. They are dried at 100 degree C and weighed.
- Difference in weight is noted.
- This procedure of drying, weighing, immersion and reweighing is repeated at least 5 times.

- Each time, change in weight is noted and it is expressed as a percentage of original weight.
- Crystallization of CaSO4 in pores of stone causes decay of stone due to weathering. But as CaSO4 has low solubility in water, it is not adopted in this test.

5. Freezing and thawing test

- Stone specimen is kept immersed in water for 24 hours.
- It is then placed in a freezing machine at -12 deg C for 24 hours.
- Then it is thawed or warmed at atmospheric temperature.
- This should be done in shade to prevent any effect due to wind, sun rays, rain etc. this procedure is repeated several times and the behavior of stone is carefully observed.

6. Hardness Test on Building Stone

For determining the hardness of a stone, the test is carried out as follows:

- A cylinder of diameter 25mm and height 25mm is taken out from the sample of stone. It is weighed.
- The sample is placed in Dorry's testing machine and it is subjected to a pressure of 1250 gm.
- Annular steel disc machine is then rotated at a speed of 28 rpm.
- During the rotation of the disc, coarse sand of standard specification is sprinkled on the top of disc.
- After 1000 revolutions, specimen is taken out and weighed.
- The coefficient of hardness is found out from the following equation:

Coefficient of hardness = 20 - (Loss of weight in gm/3)

7. Impact Test

For determining the toughness of stone, it is subjected to impact test in a Page Impact Test Machine as followed:

- A cylinder of diameter 25mm and height 25mm is taken out from the sample of stones.
- It is then placed on cast iron anvil of machine.
- A steel hammer of weight 2 kg is allowed to fall axially in a vertical

direction over the specimen.

- Height of first blow is 1 cm, that of second blow is 2 cm, that of third blow is 3 cm and so on.
- Blow at which specimen breaks is noted. If it is nth blow, 'n' represents the toughness index of stone.

8. Microscopic Test

The sample of the test is subjected to microscopic examination. The sections of stones are taken and placed under the microscope to study the various properties such as

1. Average grain size
2. Existence of pores, fissures, veins and shakes
3. Mineral constituents
4. Nature of cementing material
5. Presence of any harmful substance
6. Texture of stones etc.

9. Smith's Test

- This test is performed to find out the presence of soluble matter in a sample of stone. Few chips or pieces of stone are taken and they are placed in a glass tube.
- The tube is then filled with clear water.
- After about an hour, the tube is vigorously stirred or shaken.
- Presence of earthy matter will convert the clear water into dirty water. If water remains clear, stone will be durable and free from any soluble matter.

10. Water Absorption Test

The test is carried out as follows:

- From the sample of stone, a cube weighing about 50gm is prepared. Its actual weight is recorded as W1 gm.
- Cube is then immersed in distilled water for a period of 24 hrs.
- Cube is taken out of water and surface water is wiped off with a damp cloth.
- It is weighed again. Let the weight be W2 gm.
- Cube is suspended freely in water and its weight is recorded. Let this be W3 gm.

- Water is boiled and cube is kept in boiling water for 5 hours.
- Cube is removed and surface water is wiped off with a damp cloth. Its weight is recorded. Let it be W4 gm.

From the above observations, values of the following properties of stones are obtained.

1. Percentage absorption by weight after 24 hours =(W2 - W1) x 100 / W1
   Percentage absorption by volume after 24 hours = (W2 - W1) x 100 / (W2 - W3)
   Volume of displaced water = W2 - W3
2. Percentage porosity by volume = (W4 - W1) x 100 / (W2 - W3)
3. Density =W1 / (W2 - W3) kg/m3
4. Specific Gravity = W1 / (W2 - W3)
5. Saturation Coefficient = (Water Absorption/Total Porosity) = (W2 - W1) / (W4 - W1)

1.3 Deterioration Of Stones

The various natural agents such as rain, heat, etc. and chemicals deteriorate the stones with time.

- Rainwater
- Temperature changes
- Wind
- Frost
- Atmospheric impurities
- Vegetable growth
- Living organism
- Chemical agent

1. Rain

Rain water acts both physically and chemically on stones. The physical action is due to the erosive and transportation powers and the latter due to the decomposition, oxidation and hydration of the minerals present in the stones.

Physical Action: Alternate wetting by rain and drying by sun causes internal stresses in the stones andconsequent disintegration.

Chemical Action: In industrial areas the acidic rain water reacts with the constituents of stones leadingto its deterioration.

Decomposition: The disintegration of alkaline silicate of alumina in stones is mainly because of the action of chemically active water. The hydrated silicate and the carbonate forms of the alkaline materials are very soluble in water and are removed in solution leaving behind a hydrated silicate of alumina (Kaolinite). The decomposition of felspar is represented as

$K2Al2O3.6H2O + CO2 + nH2O = K2CO3 + Al2O3.2SiO2.2H2O + 4SiO2.nH2O$

(Orthoclase) (Alkaline carbonate) (Kaolinite) (Hydrated silicate)

Oxidation and Hydration: Rock containing iron compounds in the forms of peroxide, sulphide and carbonate are oxidized and hydrated when acted upon by acidulated rain water. As an example the peroxide—FeO is converted into ferric oxide—Fe_2O_3 which combines with water to form $FeO.nH_2O$. This chemical change is accompanied by an increase in volume and results in a physical change manifested by the liberation of the neighboring minerals composing the rocks. As another example iron sulphide and siderite readily oxidize to limonite and liberates sulphur, which combines with water and oxygen to form sulphuric acid and finally to sulphates.

2. Frost

In cold places frost pierces the pores of the stones where it freezes, expands and creates cracks.

3. Wind

Since wind carries dust particles, the abrasion caused by these deteriorates the stones.

4. Temperature Changes

Expansion and contraction due to frequent temperature changes cause stone to deteriorate especially if a rock is composed of several minerals with different coefficients of linear expansion.

5. Vegetable Growth

Roots of trees and weeds that grow in the masonry joints keep the stones damp and also secrete organic and acidic matters which cause the stones to deteriorate. Dust particles of organic or nonorganic origin may also settle on the surface and penetrate into the pores of stones. When these come in contact with moisture or rain water, bacteriological process starts and the resultant micro-organism producing acids attack stones which cause decay.

6. Mutual Decay

When different types of stones are used together mutual decay takes place. For example when sandstone is used under limestone, the chemicals brought down from limestone by rain water to the sandstone will deteriorate it.

7. Chemical Agents

Smokes, fumes, acids and acid fumes present in the atmosphere deteriorate the stones. Stones containing $CaCO_3$, $MgCO_3$ are affected badly.

8. Lichens

These destroy limestone but act as protective coats for other stones. Molluses gradually weaken and ultimately destroy the stone by making a series of parallel vertical holes in lime stones and sandstones.

1.4 Quarry

A quarry is a place where rocks, sand, or minerals are extracted from the surface of the Earth. A quarry is a type of mine called an open-pit mine, because it is open to the Earth's surface. Another type of mine, a sub-surface mine, consists of underground tunnels or shafts.

1.4.1 Quarrying

- Quarrying is the process of collecting stones from the natural rock surfaces. Site selection and methods used for quarrying for construction works is discussed.
- Quarrying of stone is completely different from mine. Mine belongs to underground operation only whereas quarry is carried out on exposed surface of natural rocks.
- So, the stones collected through quarrying are used for various engineering purposes. Stone quarrying is generally done at hilly areas where large quantity of stone is available.

1.4.2 Site Selection for Quarrying of Stones

The quarry should be selected based on some conditions as follows.

- The site should be near to human living areas where labor and tools are always available, required materials also should be available.
- At least one of type transportation facilities (road or railway or port or all) should be available.
- Clean water source should be available near the quarry site.
- Good quality and quantity of stone should be available.
- The site should be far from permanent structures like bridges, dams etc. because the vibrations due to blasting in the site may cause harm to them.
- Non-living area should be available to dump the refuse obtained in quarrying.
- Proper drainage facility should be available.
- Geological information of site should be read.

1.4.3 Considerations for Quarrying of Stones

After the site selection, some important considerations are to be followed before starting quarrying of stones. Which are as follows:

- The rock surface should be properly checked for cracks and fissures. The presence of these may cause planes in the stones, along which they may split. Then, the quarrying will be easy and quick as well as economical.

- Layout should be prepared which contains different stages involved in quarrying operation.
- The machines used should be tested to operate them easily and quickly.
- If the top surface of site contains soft soil, then it should be removed and dumped.
- The removal of stones should be done carefully otherwise there may be chances of landslides or slips which can cause severe damage to the lives of labor.

1.4.4 Methods of Quarrying of Stones

Quarrying can be done by three methods as follows:

- Hand tools
- Machine quarrying
- Blasting

1) Quarrying of Stones using Hand Tools

In case of soft stones or for smaller works, quarrying is done by using hand tools. There are various ways to quarry using hand tools and they are:

a) Excavating
b) Heating
c) Wedging

a) Excavating

Excavating is preferred in case of soft stone surfaces. Hammers, pick axes, shovels are used to excavate the stones.

b) Heating

- The top surface of rock is heated by placing wood with fuel on it. The fire will be allowed for some hours and the top surface gets heated and separates from the rock. This separated portion is removed by pick axes, crowbars etc.
- The stones obtained by heating will be in good shape if the rock formation contains horizontal layers at shallow depth. So, the stone obtained will be directly used for masonry works.

c) Wedging

- This method is applicable when the rock contains cracks or joints in it. Steel wedges or steel points are put in these cracks or fissures and hit them with hammer.
- Then the rock portion separates from parent rock. If natural cracks are there, then artificial holes are drilled in the rock and wedging is done.

2) Machine Quarrying of Stones

- Machine quarrying is done by using channeling machines in the site. This type of machine is driven by steam, compressed air or electricity.
- A groove is made using this machine around the rock and the horizontal holes are drilled underneath the block. Hence, the block gets separated from its bed.
- A large groove of 24-meter length and 50 to 75 mm width and with a depth about 2 to 3.7 meter can be made using channeling machine. So, larger blocks of stones can be obtained using this method.
- Marbles, lime stones, etc. are quarried using machine quarrying.

3) Blasting for Quarrying of Stones

- In this method explosives are used to separate the stones from parent rock. This process is applied in case of hard stone or hard rock which does not contain any cracks or fissures.
- The holes are drilled in the rock and explosives are arranged in the holes and blasted with proper safety measures. The stones obtained through this process are not larger in size.
- So, the main purpose of blasting is to obtain small stones which are used as ballast for railway works, aggregate in concrete works etc..

1.5 Preservation of Stones:

The decay of building stones of inferior quality is to some extent prevented, if they are properly preserved. For this purpose, the preservatives are applied on the stone surfaces.

An ideal preservative has the following properties:

(i) It does not allow moisture to penetrate the stone surface.

(ii) It does not develop objectionable colour.

(iii) It hardens sufficiently so as to resist effects due to various atmospheric agents.

(iv) It is easily penetrated in stone surface.

(v) It is economical.

(vi) It is non-corrosive and harmless.

(vii) It remains effective for a long time after drying.

(viii) Its application on stone surface is easy.

It should however be remembered that there is not a single preservative which is suitable for all types of stones. The choice of a preservative therefore requires careful consideration. Depending upon the chemical composition of stones and their location in structure, a particular preservative should be recommended. Each case should be properly studied before a final choice is made.

Following are the preservatives which are commonly adopted to preserve the stones:

1. Coal tar
2. Linseed oil
   - Raw linseed oil
   - Boiled linseed oil
3. Paint
4. Paraffin
5. Solution of alum and soap
6. Solution of baryta

(1) Coal Tar:

If coal tar is applied on stone surface, it preserves stone. But the colour of coal tar produces objectionable appearance and surface coated with coal tar absorbs heat of the sun. Hence this preservative is not generally adopted because it spoils the beauty of stones.

(2) **Linseed Oil:**

This preservative may be used either as raw linseed oil or boiled linseed oil. The raw linseed oil does not disturb the original shade of stone. But it requires frequent renewal, usually once in a year. The boiled linseed oil lasts for a long period, but it makes the stone surface dark.

- Raw linseed oil - it does not disturb the original shade of stone but it require frequent renewal once in a year.
- Boiled linseed oil - last for a long period but it makes stone surface dark.

(3) Paint:

An application of paint on stone surface serves as a preservative. The paint changes the original colour of stone. It is applied under pressure, if deep penetration is required.

(4) Paraffin:

This preservative may be used alone or it may be dissolved in neptha and then applied on stone surface. It changes the original colour of stone.

(5) Solution of Alum and Soap:

The alum and soft soap are taken in proportion of about 0.75 N and 0.50 N respectively and they are dissolved in a litre of water. This solution, when applied on stone surface, acts as preservative.

(6) Solution of Baryta:

A solution of barium hydroxide Ba(OH)2, when applied on stone surface, acts as a preservative. This preservative is used when the decay of stone is mainly due to calcium sulphate, CaSO4.

Following chemical reaction takes place –

$$Ba(OH)_2 + CaSO_4 = BaSO_4 + Ca(OH)_2$$

The barium sulphate is insoluble and it is least affected by atmospheric agencies. The calcium hydroxide absorbs carbon dioxide from atmosphere and forms calcium carbonate $CaCO_3$ which adds to the strength of stone.