Chapter 4

Building Stones

Stones are naturally occurring rocks that make up the crust of the earth. Those types of stone possessing such properties, which make them suitable for building construction, are defined as ***building stones***. ***Thus selection of building stones involves a study of the properties that are desirable and undesirable***.

Stones have been used extensively in construction by virtue of their being:

- Naturally available in abundance
- Very hard, strong and durable
- Suitable for taking shape of blocks, slabs, columns, beams, arches and sills

Many magnificent construction of the past are made up entirely of stones of one type or another. For instance, the Axume Stele, the Lalibela Castle, etc are made of stone.

Even though stones can be used in any part of a building: foundations, flooring, walls, columns, stairs, sills, arches, roofing etc they have limited use in the building construction in modern times because:

- Stones are not easily available every where
- Cost of dressing is high
- They are being replaced by concrete

Classification of Stones

Rocks from which building stones are obtained are classified on the basis of: a) their geologic origin, b) their chemical composition and, c) their structure.

a) Geological Classification

Rocks are divided in to three classes according to their geologic formation (mode or process of formation). These are igneous, sedimentary and metamorphic.

1) **Igneous rocks: -** rocks formed by cooling and crystallization from originally hot and molten material (magma)
   - are most abundant rocks of the crust ***depth wise***.

Based on their ***depth of solidification***, igneous rocks can be classified as:

(a) Extrusive (Volcanic) rocks: - formed on the surface of the earth, even under water in oceans
   - more rapid cooling of the molten material hence are *fine grained rocks*
   - Example: Basalt, Trachyte, etc

(b) Intrusive (Plutonic) rocks:-formed at great depth , generally from 2-10Km below the surface.
   - Slow cooling of the molten material hence are coarse-*grained rocks*
   - Example: Granite, Gabbro, etc

2) **Sedimentary rocks: -** rocks formed as a result of sedimentation from the disintegration products derived from decayed rocks (weathered/eroded rocks).
   - are widespread, ***area wise***, on the surface of the earth.
   - Examples: Sandstone, Limestone, Dolomite, shale, etc

3) **Metamorphic rocks: -** are either igneous or sedimentary rocks that have been altered ***structurally and mineralogically*** by heat or pressure or both acting together.
   - are not mostly abundant hence of minor importance for construction purposes except marble.
   - Examples: Quartzite, Marble, Gneiss, Slate, etc

b) Chemical Classification

Chemically rocks are classified on the basis of their ***dominant constituent***. These are:

1) **Siliceous rocks: -** major component is silica (SiO_2), the predominant ingredient of quartz sand, as granite and quartzite.
   - are very strong. Also when free from decomposed minerals and mica, these rocks are excellent building stones.
   - Example: Quartzite, Granite, Gneiss, etc

2) **Calcareous rocks: -** major component is carbonate ($CaCo_3$, $Mg\ Co_3$).
   - Example: Limestone, Dolomite, Marble, etc.

3) **Argillaceous rocks: -** major component is clay (alumina Al_2O_3),

- Sedimentary varieties include: clay stones, siltstones and shale-which are generally soft & disintegrating easily in the presence of water resulting in to muddy slush & hence used as building stones.
- Metamorphic varieties include: phyllites and slates-which are quite hard & brittle but thin layered and of limited use in building construction.

c) Structural (physical) Classification

Rocks are classified in to three broad classes based on the absence or presence of layered structure and when layered on the nature of layered structures.

1) **Unstratified (massive) rocks: -** most igneous rocks like granite, gabbro
2) **Stratified (layered) rocks: -** most sedimentary rocks like limestone, sandstone, shale
3) **Foliated rocks: -** most metamorphic rocks like slate, gneiss, schist

Some Common Building Stones

Granite: -igneous rock of siliceous composition and unstratified structure.

- coarse grained texture
- light colour and often spotted
- posses high strength and hardness, low absorption value, least porosity, good resistance to frost and weathering, excellent durability, appealing colour and receive finishing. Hence it is used as polished floor finishing material or cladding to external walls

-has poor fire resistance.

- shall never be used in places where it will be subjected to great heat owing to its tendency to explode due to different rates of expansion of their constituent minerals.

Basalt (Trap): -igneous rock composed of minerals like feldspars and ferromagnesian minerals like hornblende.

- fine grained texture which sometimes has pores due to escape of gases at the time of cooling.

- dark or light dark in colour

- posses very high strength, high resistance to weather, less permeability

- common in Ethiopia and mostly used for stone masonry work and as boulders or crushed stone for road construction & crushed aggregate for concrete making.

- shall never be used in places where it will be subjected to great heat owing to its tendency to explode due to different rates of expansion of their constituent minerals.

Limestone: -sedimentary rock of calcareous composition ($CaCo_3$) and generally stratified (sometimes massive).

- are invariably fine textured and some may contain fossils.
- colour from pure white (chalk) to grey & dark varieties depending on its content of clay, iron oxide or other impurities
- some lime stones which are rich in clay or soft are ***practically unfit for construction***. But some others, which are dense, compact, fine textured and free from cavities and cracks are ***excellent building stones***.

The use of limestones as facing stones should be avoided in areas where the air is polluted with industrial gases and also in coastal regions where saltish winds can attack them. In both cases, air is likely to attack the rock chemically and change its surface to spots of reactive compounds.

Sandstone: -sedimentary rock of siliceous composition (quartz SiO_2) and mostly stratified.

- the cementing material may be siliceous, ferruginous, calcareous or clayey in nature. And, this is the most important in defining the suitability of sand stone for building construction is concerned.
- medium to fine grained texture.
- many colors: white, grey, pink, red and dark

- some sandstone varieties which are light colored, rich in quartz, having a siliceous cement and fine grained uniform texture are excellent building stones. But they must be free from fine layers or minerals like mica & chlorite

Marble: -metamorphic rocks of calcareous composition and often-layered structures.

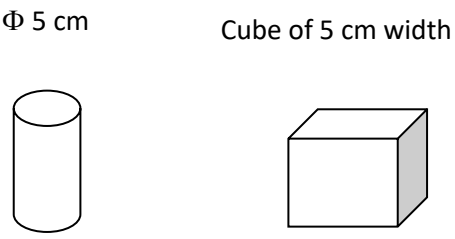
- formed from limestone through metamorphism thus contain recrystalized calcite $CaCo_3$.
- fine grained texture with a uniform granular (sugar like grains).
- occurs in all colors: from white to dense.
- quite strong, uniform in texture, least porous and take excellent polish. Thus are suitable for both as ornamental & for general construction.

Tests on Building Stones

In practice building stones are used for construction purposes as quarried and are rarely tested. How ever, it is at times useful to know some of the characteristics of a particular stone & some or all of the following tests can be done.

1) Test for Compressive Strength

Test Samples:



Test procedure: Test shall be carried on ***saturated*** as well as on ***dry samples***

Saturated: immerse samples in water at 20-30^{o}C for 72 hrs and then test in saturated condition.

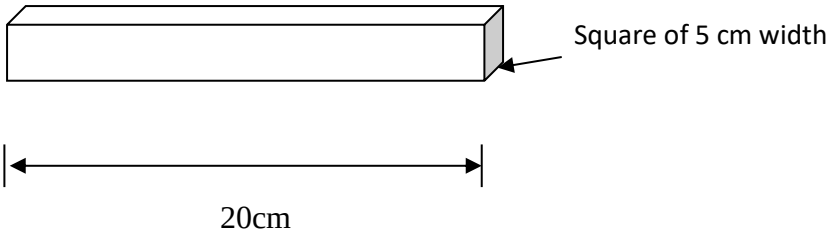
Dry: oven dried at 105+5^{o}C for 24 hrs. Then cooled in a desiccator to room temperature.

Loading: Load increased gradually till the sample yields, i.e. first crack appears in it.

Compressive strength: σ_c=P/A where P= load at failure, A= area of the sample

2) Test for Transverse Strength

Test Samples:



- Properly dried and smoothened.

Test procedure: Test shall be carried on ***saturated*** as well as on ***dry samples***

Loading: One point loading.

Modulus of rupture: $R=3PL/2bd^2$

3) <u>Test for Water Absorption and Bulk specific gravity</u>

Test Samples: Cubes, prisms, cylinders or any regular form with dimensions ≥ 50 & $\leq$ 75mm and $(0.3 \leq V/\text{surface area ratio} \leq 0.5)$

Absorption capacity by weight (%) = [(B-A) /A] x100

Where: A= wt of specimen after oven drying at 105+2^{o}C for 24 hrs

B=Weight of SSD specimen (saturation in water at 20$\pm$5^{o}C for 48 hrs)

Bulk specific Gravity = A/(B-C)

Where: A= wt of specimen after oven drying at 105+2^{o}C for 24 hrs

B=Weight of SSD specimen in air (saturation in water for 1hr on the specimen which has been oven dried for 24 hrs)

C=Weight of Soaked specimen in water.

It is generally observed that the strength of building stones increase with increasing sp.gr. Also the higher the sp.gr., the grater the stability of a hydraulic structure built on stone.

Table: Physical properties of some selected stones

Type of stone	Specific gravity	Absorption	Compressive strength, Mpa
Basalt	2.7-2.9		100-200
Granite	2.7-2.9		100-200
Trachyte	-		-
Pumice	-		-
Scoria	-		-
Limestone	2.0-2.7		10-60
Sandstone	2.5-		15-150
Marble	2.6-2.7		80-150

Test for weathering resistance (temp. change, salt crystals in pores) and for durability can also be made using chemicals in the same way as aggregates.