# UNIT – 3

## Subject – Engg. Geology

**Topics covered in this content** - Engineering Properties of rocks, Alkali Aggregate Reaction, Grouting, Pozzolanic Materials, Fly ash

## Part 3

## Engineering Properties of Rocks

Engineering properties of rocks is a collective nomenclature which includes all such properties of rocks that are relevant to engineering application after their extraction from natural beds or without extraction i.e. *insitu* conditions. This include all those properties for which a rock must be tested for selection as a material for construction such as a building stone, road stone or aggregate for concrete making. The second set of the properties include the qualities of a natural bed rock as and where it exists. That would determine its suitability or otherwise as a construction site for a proposed engineering project.

### 1. Crushing Strength

It is also termed as compressive strength of a stone. It may be defined as maximum force expressed per unit area which a stone can withstand. Any force beyond the compression strength will cause a failure of the stone. Mathematically, compressive strength is expressed by simpler method as follows

$$C_o = P/A$$

Where $C_o$ = Compressive strength, $P$= Load at failure, $A$ = Area of cross section of stone under $P$

The determination of compressive strength of a building stone involves making standard test specimens (which are either cubes of 5cm side or cylinders of length: diameter ratio of 2 or 2.5). These specimens are then loaded gradually one at a time after placing on the base plate of a universal testing machine, till the first crack appears in the specimen. Any further loading will crush the specimen. The compressive strength determined in this way using the above relationship is called "unconfined or universal compressive strength". Because the test specimen has no lateral support or restraint.

When the compressive strength is tested by a method providing a lateral support , as by keeping the specimen in a special cell filled with a liquid under pressure. The value obtained, then it is called as confined or triaxial compressive strength.

The crushing strength of a rock depends on a number of factors, such as its

i. Mode of formation
ii. Composition
iii. Texture and structure
iv. Moisture content and
v. extent of weathering it has already suffered

Igneous rocks are crystalline rocks. They are compact and characterized by interlocking in texture and uniform in structure. These rocks possess very high crushing strengths compared to sedimentary and metamorphic rocks. In the sedimentary and metamorphic rocks, the presence of planes of weakness along bedding planes, greatly affects the compressive strength, both in direction and magnitude.

The sand stone may show a very low crushing strength when loaded parallel to bedding planes than when loaded perpendicular to the same structure. Except for sandstone, quartzite and most other sedimentary and metamorphic rocks are composed of clays, calcareous and hydrated silicate minerals which are inherently weak is strength.

Crushing strengths of common types of building stones are generally higher than the loads that they are supposed to withstand, in ordinary type of building constructions.

The compressive strengths of some rocks and their range are as follows. They are expressed in Kg/cm2. Dolerite=1500-3500, Basalt= 1500-3500, Quartzite=1500-300, Granite= 1000-2500, Marbles=700- 2000, Gneisses=500-2500, Sand Stone= 200-2500, Limestone= 200-2000.

During the last few years thousands of tests have been made to classify the rocks on the basis of uniaxial compressive strength in to grades. The following classification proposed by Deere and Miller has been found usefull.

| Class | Description | Uniaxial compressive strength(Kg/cm2 |
|---|---|---|
| A | Very high strength | More than 2240 |
| B | High strength | 1120—2240 |
| C | Medium strength | 500—1120 |
| D | Low strength | 200—500 |
| E | Very low strength | less than 200 |

## 2.Transverse strength:

It is defined as the capacity of the stones to withstand bending loads. Such loads are only rarely involved in situations where stones are commonly used. But when a stone is intended for use as a beam or a lintel, its transverse strength is determined as modulus of rupture using the following relationship.

$$R = 3WL / 2bd^2$$

R = Modulus of rupture; W = weight at which sample breaks; $l$= length of the specimen; $b$ = width of specimen; $d$ = thickness of the specimen.

This property is determined practically by loading transversely a bar shaped test specimen generallyof 20cmsx8cmx8cm dimension and is supported at ends from below.

It has been found that in stone, the transverse strength is generally $1/20^{th}$ to $1/10^{th}$ of their compressive strengths.

## 3.Shear Strength :

Shear strength is the resistance offered by a stone to shear stresses, which tends to move one part of a specimen with respect to the other. It is obtained by using the relationship. Shear strength of a stone is also not commonly determined except when the stone is to be used as a column

$$S = P/2A$$

Where P = load at failure; A = area of cross section of the specimen.

It has been observed that shear strength of most common building stones ranges from 70 to 140 kg/cm2.

In laboratory testing, a bar shaped specimen is held with grip andis supported at ends below, is loaded from above. Rupture occurs when the shear strength is exceeded.

## 4.Porosity :

The shape, size and nature of packing of the grains of a rock give rise to the property of porosity or development of pore spaces within a rock. Numerically it is expressed as the ratio between the total volume of pore spaces and the total volume of the rock sample. Porosity is commonly given in percentage terms. Presence of interlocking crystals, angular grains of various sizes and abundant cementing materials are responsible for low porosity of stones.

Conversely the rock will be highly porous it composed of spherical or rounded grains, (sandstone) or if the cementing material is distributed unevenly or is of poor character.

Porosity is an important engineering property of rocks. It accounts for the fluid absorption value of the stones in most cases and also that a higher porosity signifies a lesser density which generally means a lesser compressive strength. Porosity values for a few common building stones. Granite-0.1 to 0.5%, Basalt- 0.1 to 1%, Sandstone- 5 to 25%, Limestone- 5 to 20%, Marble- 0.5 to 2%, Quartzite- 0.1 to 0.5%.

## 5.Absorption Value:

It defines the capacity of a stone to absorb moisture when immersed in water for 72 hours or till it gets full saturation.It is generally expressed in percentage terms of original dry weight of the mass. . It maybe obtained from the relationship

**Absorption Value = (Ws-Wo)/Wo *100**

Where Ws = weight at saturation; W0 = dry weight of the sample used.

## 6.Permeability:

It is the capacity of a rock to transmit water. Sand stones and limestones may show high values for absorption or 10% or even more. Selection of such highly porous verities of these stones for use in building construction, especially in most situations, would be greatly objectionable.

Presence of water within the pores not only decreases the strength of the rock but also makes the stones very vulnerable to frost action, in cold and humid climatic conditions.

## 7.Density :

It is defined as weight per unit volume of a substance.But in the case of rock it is not only the solid mineral matter which wholly accounts for the total volume of a given specimen.A part of the rock may comprise of pores or open spaces, which may be empty, partly filled or wholly filled with water. Accordingly, three types of density may be distinguished in rocks. They are a)Dry density, b) bulk density and c) saturated density.

1.**Dry density**: It is the weight per unit volume of an absolutely dried rock specimen, it includes the volume of the pore spaces present in the rock.
2.**Bulk density**: It is the weight per unit volume of a rock sample with natural moisture content where pores are only partially filled with water.
3.**Saturated density**: It is the density of the saturated rocks or weight per unit volume of a rock in which all the pores are completely filled with water.
The fourth type is also recognized as true density. Itis the weight per unit volume of the mineral matter(without pores and water) of which a rock s made up. The most engineering calculations, it is the bulk density which is used frequently.
Bulk density values in gram/cubic cm for some common building stones are granite-2.7, basalt-2.9, sandstone-2.6, and limestone-2.2 to 2.6.

## 8.Abrasive Resistance :

It is more a qualitative than a quantitative property. It may be broadly defined are the resistance which a stone offers to rubbing action of one kind or another.Determination of this is of considerable significance when stones are intended for use in situations where rubbing by natural or artificial causes is involved as a routine.Example a) stones used in paving along roads, b) Facing stones in buildings of arid region where strong sand laden winds are blown.These type of situations demand stones that have not only high abrasive resistance but also of essentially uniform, composition. So that thewear is as uniform as possible.

Stones composed of more than one mineral like granite may look quite appealing. In such cases, when freshly used, but within short time, they may get pitted or disfigured because of unequal wear of the different mineral components.

## 9.Frost and fire resistance

Many building stones show quick disintegration of building stones or rocks when used in situations involving frost formation (excessive cold) or heating. Frost causes disintegration by expansion of water on breezing within the rock pores.

In the case of fire, the unequal expansion in different mineral components and also at different depths from surface inwards may cause disintegration. This effect becomes more pronounced when the rock is first heated and then suddenly cooled by water by water. Heavy stones including granites crumble to piecesunder such a treatment. It is easy to understand that rocks which are found porous and weak in strength are easily deteriorated in cold humid climates by frost action. Limestone and sandstones fall in this category. They show very poor frost resistance.

Fire resistance is especially determined when the stone is intended for use around stoves, heating places and in the wall of furnaces. Only compact and massive sandstones and quartzites suite reasonably well in fire and heating places.

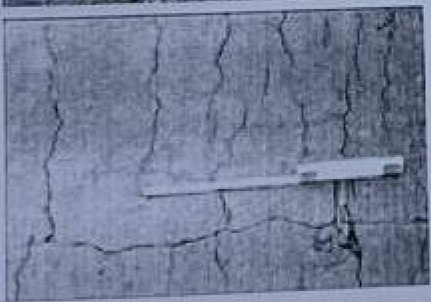
## 10.Tensile Strength:

Tensile strength of a rock is related to its ability to withstand breakage. It happens after some level. That level is its strength. It may be determined directly or indirectly. The tensile (pulling) strength that has to be applied to a material to break it. It is measured as a force per unit area. The direct method would require elaborate means to avoid bending while applying tensile forces by gripping the specimens at the ends. Since tensile stresses are seldom required accurately, an indirect method is commonly applied.

The indirect method is called the Brazilian test. It consists of loading a test cylinder diametrically in such a way that the applied loads would develop tensile rupturing along the diametrical plane of the specimen.

# Alkali Aggregate Reaction

In most concrete, aggregates are more or less chemically inert. However, some aggregates react with the alkali hydroxides in concrete, causing expansion and cracking over a period of many years. This alkali-aggregate reaction has two forms: alkali-silica reaction (ASR) and alkali-carbonate reaction (ACR).



***Alkali-silica reaction (ASR)*** is of more concern because aggregates containing reactive silica materials are more common. In ASR, aggregates containing certain forms of silica will react with alkali hydroxide in concrete to form a gel that swells as it adsorbs water from the surrounding cement paste or the environment. These gels can induce enough expansive pressure to damage concrete.

Typical indicators of ASR are random map cracking and, in advanced cases, closed joints and attendant spalled concrete. Cracking usually appears in areas with a frequent supply of moisture, such as close to the waterline in piers, near the ground behind retaining walls, near joints and free edges in pavements, or in piers or columns subject to wicking action.

**Alkali-silica reaction** can be controlled using certain supplementary cementitious materials. In-proper proportions, silica fume, fly ash, and ground granulated blast-furnace slag have significantly reduced or eliminated expansion due to alkali-silica reactivity. In addition, lithium compounds have been used to reduce ASR. Although potentially reactive aggregates exist throughout North America, alkali-silica reaction distress in concrete is not that common because of the measures taken to control it. It is also important to note that not all ASR gel reactions produce destructive swelling.

***Alkali-carbonate reaction (ACR)*** is observed with certain dolomitic rocks. Dedolomitization, the breaking down of dolomite, is normally associated with expansion. This reaction and subsequent crystallization of brucite may cause considerable expansion. The deterioration caused by alkali-carbonate reactions is similar to that caused by ASR; however, ACR is relatively rare because aggregates susceptible to this phenomenon are less common and are usually unsuitable for use in concrete for other reasons. Aggregates susceptible to ACR tend to have a characteristic texture that can be identified by petrographers. Unlike alkali carbonate reaction, the use of supplementary cementing materials does not prevent deleterious expansion due to ACR. It is recommended that ACR susceptible aggregates not be used in concrete.

## Grouting

Grouting is generally a mixture of cement, sand and water.
Different type of grouting are used for different purposes but generally They are used in the purpose of repairing of concrete cracks, filling seams and gaps in tiles, seal and fill gaps for waterproofing courses, and for soil stabilization in boring well and foundation. It is also used to give extra strength to the foundations of load-bearing structures.

Grouting is the application that we utilize a mix of cement and sand along with other material (such as epoxy) to fill the spaces that may result during some construction operation. for example, one type of prestressing in concrete is the post tensioning process. In this process we install tubes in concrete beam or slab then we cast concrete, after concrete hardening we insert steel strands inside tubes for prestressing. the space that will result between steel strands and inside wall of the tube is filled afterwards by grouting.

## Pozzolonic Materials :

Pozzolanic materials are siliceous and aluminous materials, possessing little or no cementitious value by themselves, but in finely divided form and in the presence of moisture react chemically with calcium hydroxide liberated on hydration of cement at ordinary temperature to form compounds, possessing cementitious properties.

The Silicious or aluminious compounds in a finely divided form react with calcium hydroxide to form highly stable, cementitious substances of complex composition involving calcium, silica and water. Generally amorphous silicate reacts much more rapidly than the crystalline form. The calcium hydroxide a water soluble material is converted into insoluble cementitious material by the reaction of pozzolanic materials.

Initially the pozzolanic reaction is slow and thus the production of heat of hydration and development of strength is also slow. The reaction involves the consumption of $Ca(OH)_2$ and thus there is no production of $Ca(OH)_2$. The reduction of $Ca(OH)_2$ increases the durability of cement paste by making the cement paste dense and impervious.

**Pozzolanic materials may be divided into two groups:**

*1. Natural Pozzolanic Materials:*

**Under this group following materials can be grouped:**

1. Calcined diatomaceous earths

2. Volcanic ash, tuffs and pumicites

3. Opaline cherts

4. Clay and shales

Natural pozzolans need further grinding and calcining to activate them. Nowadays they have lost their popularity due to the availability of more active artificial pozzolans.

## *2. Artificial Pozzolanas:*

**Under this group following substances are grouped:**

1. Silica fume

2. Fly ash

3. Blast furnace slag

## ***Fly Ash:***

It is a finely divided residue from the combustion of powdered coal. It is a waste product from coal fired power stations and Railway locomotive etc. It is the most common artificial pozzolana material. The fly ash particles are spherical and of the same fineness as that of cement. Thus silica is always readily available for reaction.

The pozzolanic activity of fly ash is good but it is essential that it has constant carbon content and constant fineness. The use of fly ash in concrete as an admixture not only extends the technical advantage to the properties of concrete, but it also contributes to the environmental pollution control.

**Effect of Fly ash on Fresh Concrete:**

The use of right quantity of fly ash is found in the reduction of water content required for the production of desired slump. With the reduction of water content in concrete, bleeding and drying shrinkage is also reduced. As fly ash is not highly reactive, the heat of hydration can also be reduced by the replacement of a part of cement with fly ash. 30% replacement of cement by fly ash has been found to reduce the rise of temperature by about 6°C as shown in Fig.6.12.

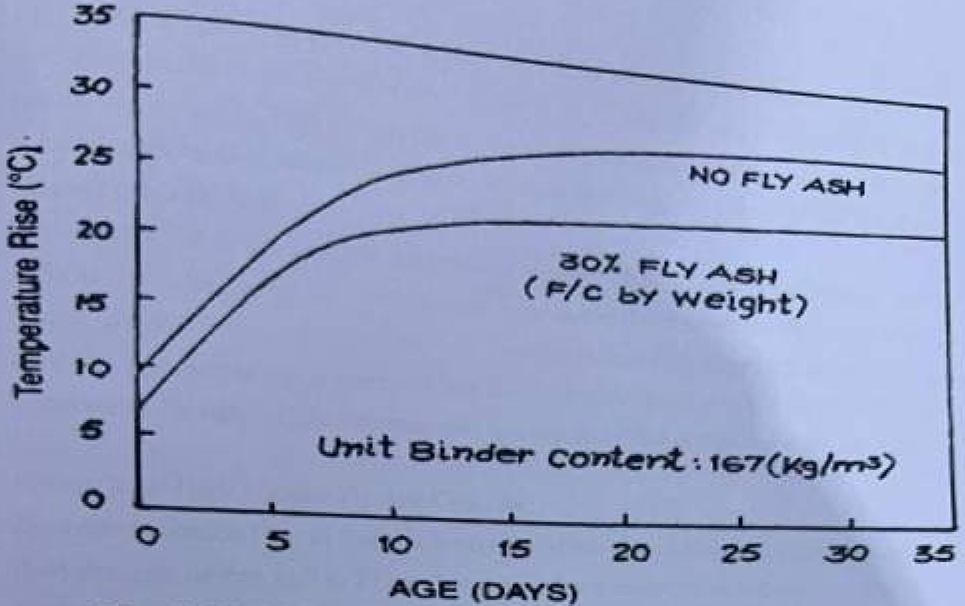



**Fig. 6.12. Change in rate of the heat evolution of concrete with and without fly ash**

**Effect of Fly Ash on Hardened Concrete:**

Fly ash is an industrial waste, but the use of good quality fly ash in concrete has shown following effects on the concrete properties.

**They are:**

1. Fly ash being a pozzolanic material, its reaction takes place slowly. The initial strength of fly ash concrete is less than that of concrete without fly ash sufficiently but the strength at the later age is much greater than that of concrete without fly ash.

2. Fly ash also develops dense texture of concrete, resulting in the decrease of permeability of concrete.

3. As pozzolanic reaction can take place only in the presence of water, thus fly ash concrete needs long curing period for the development of strength. Thus it should be cured for longer period.

4. The use of good quality fly ash reduces the heat of hydration.

5. It also increases the durability of concrete.

**High Volume Fly Ash Concrete (HVFA):**

At present India generates about 100 x 10⁶ tonnes of fly ash and out of which about 5% is utilised in making blended or pozzolanic cement, in which 10 to 30% addition of fly ash of the cement content is permissible. Thus the disposal of fly ash has become a serious problem. One of the practical approaches to reduce the disposal problem of fly ash is to popularise the use of high volume fly ash concrete.

The high volume fly ash concrete is a concrete in which 50 to 60% fly ash is incorporated. First it was developed for use for the mass concrete structures as dams where the development of low heat of hydration is the main consideration. Later on the use of this concrete showed excellent durability and mechanical properties required for structural and pavement constructions. It is also found useful for light weight concrete, shot creating and roller compacted concrete.

**Properties of High Volume Fly Ash Concrete:**

**Experiments carried out at Canada centre for Mineral and Energy Technology with more fluid concrete having 18.0 to 20 cm slump have been observed as follows:**

**1. Bleeding and Setting Time:**

Due to the low water content in high volume fly ash concrete, bleeding also is very low. The setting time is little longer than that of conventional concrete. Its use in cold weather concreting should be done with great care. The form work cannot be removed early as in the case of ordinary cement concrete.

**2. Heat of Hydration:**

Due to low contents of cement, its heat of hydration is low. Experiments have shown that the heat of hydration of high volume fly ash is 15 to 25% less than ordinary concrete without fly ash.

**3. Curing Period:**

The high volume fly ash concrete has to be cured effectively for longer period than ordinary as well as normal fly ash concrete to obtain the continued pozzolanic reaction for the development of strength. It should be properly protected from pre-matured drying by covering the surface properly.

**4. Durability of (HVFA) Concrete:**

Investigations carried out in Canada & U.S.A. has shown that high volume fly ash concrete has excellent durability.

**Mechanical Properties:**

Its mechanical properties also have been found excellent.

### Use of High Volume Fly Ash:

Laboratory and field experiments have shown that concrete containing 55 to 60% high volume fly ash has excellent structural and durability characteristics. Hence after 1985, high volume fly ash has been used in the construction of many high rise buildings, industrial structures, concrete roads and Roller Compacted Concrete dams etc. There is bright future for this material due to sound economy and usefulness to utilize the large waste and harmful material.

Slag is a waste product of the manufacture of pig iron. It is a nonmetallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching it in water to form a glassy and granulated material like sand.