GEOLOGY SEMESTER IV

GT 403 – ENGINEERING GEOLOGY AND ENVIRONMENTAL GEOLOGY

UNIT 1.2
ENGINEERING PROPERTIES OF ROCKS
UNIT 1.3
STRENGTH OF ROCKS

Objectives

- The aim of this lesson is to understand the important physical properties of rocks and their determination, geological characteristics, general characteristics, modulus properties of rocks, building stones and their occurrences. The role of a geotechnical engineer is also highlighted.

Introduction

- 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. The first set 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.

- Obviously, in both cases, the economy and safety of an engineering project are greatly dependent upon the proper understanding and determination of the engineering properties of rocks. Engineering properties of rock are controlled by the discontinuities within the rock mass and the inherent properties of the intact rock. Therefore, engineering properties must account for the properties of the intact rock and for the properties of the rock mass as a whole.

- A combination of laboratory testing of small samples, empirical analysis, and field observations should be employed to determine the requisite engineering properties. Rock properties can be divided into two categories: intact rock properties and rock mass properties. Intact rock properties are determined from laboratory tests on small samples typically obtained from coring, outcrops or exposures along existing cuts. Common engineering properties typically obtained from laboratory tests include specific gravity, point load strength, compressive strength, tensile strength, shear strength, modulus, and durability.

Physical properties of rocks:

- In most of the engineering applications, rocks are used as building stones. A building stone may be defined as a rock that can be safely used as a rough unit or as a properly cut and shaped (dressed) block or slab or column or sheet in different situation in an engineering construction. The following physical properties are considered to be important for a rock to be used as a building material.

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

$$C_0 = P/A$$

- Where 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, foliation and schistosity and cleavage, 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

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 generally of 20cmsx8cmx8cm dimension and is supported at ends from below.
- It has been found that in stone, the transverse strength is generally 1/20th to 1/10th of their compressive strengths.

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.

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 calledthe 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.
- Loads are gradually increased till the cylinder fractures. The load *P,* at rupture being thus known. Transverse strength Ts is calculated by using the formula

$$T_S=2P/\mu DL$$

- D = diameter of the specimen; L = length of the specimen

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%

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

$$\textit{Absorption Value} = W_S - W_0 / W_0 \times 100$$

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

Permeability

- It is the capacity of a rock to transmit water. Sand stones and limestone 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.

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. It is 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.

Elastic properties of rocks

- The elasticity of rocks indicates their deformation under loads. The deformation is recovered when loads are removed. It is determined in accordance with Hook's law which states that in elastic substances stress is directly proportional to strain.
- It is expressed by the relationship
- Q/E=E
- Where Q= stress, E= Strain, E= Modulus of elasticity, It is also termed as young's modulus.
- It is tested for rocks by loading test specimens usually a cylinder of L/D ratio 2, Under uniaxial compression and sometimes tension.
- The axial deformation i.e. change in parallel to stress direction is determined at the application of each increment of load using strain gauges. This process of loading and determining the strain is continued till the specimen actually breaks.
- That is the ultimate limit up to which the specimen could be deformed. The limit up to which it remains elastic i.e. recovers the original shape when the load is removed is reached slightly earlier.

- Rocks are highly anisotropic so far as their elastic constants are concerned. They show all varieties ranging from perfectly elastic to practically inelastic. This depends on their composition, texture and structures. It is possible to broadly group the rocks into three categories, based on their Modulus of elasticity.
- **Quasi elastic:**
- These are rocks in which the stress-strain relationship is expresses by almost a straight-line till the point of failure. Such rocks include massive, densely packed uniformly structured verities of igneous sedimentary and metamorphic groups such as Syenites, Diorites,Dolerites, gabbros, basalts and quartzites.Quasi elastic rocks show E values ranging from 6x10 to the power of 5 to 11x 10 to the power of 5 kg/cm2.
- **Semi elastic Rocks:**
- Are coarse, grained slightly open packed with some porosity and very minor in any structure discontinuities. The semi elastic rock show E value range between 4x10 to the power of 5 to 6x10 to the power of 5 kg/cm2. Coarse grained igneous rocks like granites, some massive compact sediments like Sandstones and dolomite may often show semi elastic properties. In this group the curve indicating the modulus of elasticity. Such a characteristic that is slope tends to decrease with increasing loads.

. **Non elastic Rocks**

- Are those in which stress strain relationship tends to break in two zones. A initial zone of steep slope followed by a curve of least slope. These are open textured coarse grained and rich in structural discontinuities. Values of E obtained with such rocks are commonly of the order of less than 4x10 to the power of 5 kg/cm2.

Conclusion

- It is a well-known fact that rocks play a vital role in constructing the structures which are destined to be strong, appealing and economical.
- All the factors which have been considered so far give a clear guideline for an engineer to choose the right type of naturally occurring rocks or stones to be used to build such structures.
- By choosing all the properties judiciously in conjunction with one another, it is possible to adhere to the safety regulations prescribed in building standards. A combination of laboratory testing of small samples, empirical analysis and field observations should be employed to determine the requisite engineering properties.
- Engineering properties of rocks are very essential properties to be determined in every project of civil engineering, construction engineering and structural engineering.