*TITLE OF THE CHAPTER:*

**Engineering behaviour of rocks and soils (properties).**

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**Abstract**:

*Understanding the physical qualities of rocks and soils and how they relate to geological characteristics, general characteristics, and modulus properties of rocks and soils is the goal of this course. Geology offers organized knowledge of building materials and their characteristics. The stability of civil engineering structures including buildings, pavement constructions, dams, bridges, tunnels, and subway systems, among others, is influenced by the geological and geotechnical qualities of soils. It goes without saying that a proper understanding and assessment of the engineering properties of rocks and soils are essential to the safety, stability, and economy of engineering constructions. Thus, we explore the engineering behaviour (properties) of rocks and soils in this chapter.*

*Key words: Rock, Soil, Hardness, Porosity Permeability, Structure, Texture, Density, Fracture, Cleavage, Shear strength, Foundation, Stability etc.,*

**1. INTRODUCTION**

The term "engineering behaviour of rocks and soils" refers to all of the characteristics of rocks and soils that are important for engineering applications, whether they have been extracted from their natural formations or are still present in the ground. The first set includes all the characteristics that must be checked before a rock is chosen as a building stone, road stone, or aggregate for concrete production. The attributes of a natural bed rock as it is found comprise the second set of the properties. That would decide whether or not it was appropriate to use it as a construction site for a planned engineering project.

Most constriction materials come from naturally occurring rock and soil formations. However, modern ways using equipment and artificially created materials can replace it. As a result, one of engineering's goals is economy, which is why we should employ and utilize natural products.

To ascertain the necessary engineering properties, a combination of laboratory testing of small samples, empirical analysis, and field observations should be used. Intact rock properties and rock mass properties are the two categories into which rock properties can be separated. Laboratory testing on small samples, often taken from coring, outcrops, or exposures along existing cuts, are used to determine the characteristics of whole rock. Common engineering qualities including specific gravity, point load strength, compressive strength, tensile strength, shear strength, modulus, and durability are often determined by laboratory experiments.

Visual inspection and description of discontinuities within the rock mass are used to determine the characteristics of the rock mass. The approach recommended by the International Society of Rock Mechanics (ISRM 1978) should be used to determine how these discontinuities will affect how the rock mass behaves under the planned construction.

Rocks mechanically disintegrate or decompose chemically, resulting in the formation of soil. The physical, chemical, and engineering qualities of the soil that are used for the surface layers and subsurface that are affected by the strains from the loads exerted on it are very significant and necessary in civil engineering. Some of the most frequent foundation issues nationwide are settlement and sinking in the foundation. The weak bearing capacity of the soil, poorly compacted soil, variations in the amount of moisture in the soil, mature trees with roots, and other plants, as well as soil consolidation, are soil characteristics that cause foundations to settle. Therefore, determining the qualities of the soil is crucial in determining if it is suitable for building construction.

**2. ENGINEERING PROPERTIES OF ROCKS**

Rocks are employed as construction materials in the vast majority of engineering applications. A rock that may be utilized safely as a rough unit or as a correctly cut and shaped (dressed) block, slab, column, or sheet in various situations in an engineering construction may be referred to as a building stone. The following physical characteristics of a rock are thought to be crucial for its usage as a building material.

2.1. CRUSHING STRENGTH

Crushing power It is also known as a stone's compressive strength. It can be explained as the greatest force that a stone can withstand when stated per unit area. Any force more than the compression strength will result in the stone failing.

Class Description Uniaxial compressive strength (Kg/cm2

A Very high strength (competency) More than 2240

B High strength (competency) 1120—2240

C Medium strength (competency) 500—1120

D Low strength (competency) 200—500

E Very low strength (competency) less than 200

2.2. TENSILE STRENGTH

A rock's resistance to breaking is correlated with its tensile strength. It occurs after a certain level. Its strength is at that level. Either a direct or indirect determination may be made. the amount of tensile (pulling) force required to break a material. It is calculated as a force per square inch. By grasping the specimens at their ends, the direct technique would require complex ways to prevent bending while applying tensile stresses. An indirect technique is frequently used since precise measurements of tensile stresses are infrequently necessary.

The Brazilian test is the name of the indirect approach. It entails loading a test cylinder diametrically in order to develop tensile rupturing along the specimen's diametrical plane under the applied loads.

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

 TS=2P/µDL

 D = diameter of the specimen

 L = length of the specimen

2.3. TRANSVERSE STRENGTH

The ability of the stones to sustain bending stress is how it is characterized. In contexts where stones are often employed, such loads are incredibly uncommon. However, when a stone is meant to be used as a beam or lintel, its transverse strength is calculated as a rupture modulus using the relationship shown below.

 R=3WL/2bd2

 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 feature is practically assessed by loading transversely a bar-shaped test specimen, which is typically 20 cm long, 8 cm wide, and supported at both ends from below. It has been discovered that the transverse strength of stone is typically between one twentieth and one tenth of its compressive strength.

2.4. POROSITY

The porosity, or development of pore spaces within a rock, is a quality that results from the size, shape, and packing of the rock's grain. The ratio of the total volume of pore spaces to the entire volume of the rock sample is how it is stated numerically. Porosity is frequently expressed as a percentage. Low porosity of stones is caused by the presence of interlocking crystals, angular grains of varying sizes, and an abundance of cementing ingredients.

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 particularly in hydraulic structures. 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}

2.5. ABSORPTION VALUE:

It describes a stone's ability to absorb moisture when submerged in water for 72 hours or until fully saturated. It is typically represented as a percentage of the original dry mass weight. It might be acquired through the connection.

 Absorption value = (WS-WO/WO)\*100

2.6. PERMEABILITY:

It is a rock's ability to transfer water. Sandstones and limestone’s may have high absorption levels of 10% or even more. It would be exceedingly disagreeable to use such highly porous varieties of these stones for usage in building construction, especially in the majority of cases. In cold and humid climates, the presence of water within the pores not only reduces the strength of the rock but also renders the stones extremely vulnerable to frost action. {5}

2.7. DENSITY:

It is described as a substance's weight in relation to its volume. However, when it comes to rock, it's not just the solid mineral substance that fully accounts for the specimen's overall volume. Rock may include pores or open holes that are either empty, partially or completely filled with water. As a result, there are three distinct forms of density in rocks. Dry density, bulk density, and saturated density are among them.

* 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.
* 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.
* 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-2.9, basalt-3.2., sandstone-2.2, and limestone-2.2 to 2.4.

**3. GEOLOGICAL PROPERTIES OF ROCKS**

3.1. MINEROLOGICAL COMPOSITION:

Quartz group, Feldspar group, Mica group, Pyroxene group, Amphibole group, etc. are the typical minerals that create rocks; consequently, silicate structures play a crucial part in the creation of rock as a source of strength. In terms of composition, Silica, Aluminium, Magnesium, Calcium, Phosphates, and Iron play crucial roles in the production of any rock.

Smaller units of the minerals make up rocks. Their characteristics are determined by the nature and make-up of these minerals. The strongest rocks in every way are those made primarily of silica (SiO2), especially when they are in free form.

Wide variations in their characteristics can be seen in carbonate rocks. Before a particular deposit of these rocks is suggested for use in any significant engineering building, it must be examined by taking random representative samples. When employing certain minerals in building stones, even in trace amounts, vigilance should be exercised. These minerals include chert, flint, mica, gypsum, sulphides, and tremolite. These reduce the rock's natural strength.

3.2. STRUCTURE AND TEXTURE:

 Texture defines the size, shape and mutual relationship of the mineral compounds in a rock. Whereas structure determines the development of large scale features in the rock mass as a whole. Rocks may be coarse grained, medium grained or fine grained.

It is the mutual arrangement of various mineral grains that imparts design pattern to the rock type. From simple evenly distributed to weakly, moderately and strongly foliated and then to strongly gneissic, the rock type exhibits a range of design patterns.

Compared to rocks with coarse grains and inequigranular textures, rocks with fine grains and equigranular textures make better building stones. The reaction that is supplied in the latter situations is complex and unquestionably weaker because distinct compounds frequently have a tendency to function as separate units under the applied pressures.

**4. GEOTECHNICAL PROPERTIES OF SOILS:**

The main components of soil are minerals, which are created when parent material is worn or fragmented. In soil, both plants and animals play significant roles.

There are numerous ways in which soil composition and structure are altered by both plants and animals. Plants with roots use their roots to draw moisture and nutrients from the soil. Physical, chemical, and biological characteristics of soils define them. Additionally, soils provide excellent building materials for engineering projects. Another aspect of soils is its usage as a foundation, in buildings, and in industrial settings. Understanding the engineering qualities of soils and their importance is the goal of this module's study.

Black soils, Red soils, Laterite soils, Desert soils, Mountain soils, Alkaline soils, Marshy soils, Residual soils, Alluvial soils, Marine soils, Aeolian soils, Glacial soils, Clay soils, etc. are a few examples of the numerous types of soils found in our country. {10}

4.1. COHESION:

Internal molecular attraction is what prevents a substance from rupturing or being sheared. In fine-grained soils, cohesion results from water films that hold the individual soil mass particles together.

Cohesion is a characteristic of fine-grained soil with particles smaller than 0.002 millimeters. As moisture content rises, a soil's cohesiveness reduces. Well-compacted clays have stronger cohesion, which is unaffected by the external strain.

Standard compaction tests are challenging to conduct on cohesionless soils (also known as soils without any particles). Vibration application is the most efficient technique for compaction. Watering is a further tactic. The soil grains occupy a more stable position due to the seepage force of water that percolates through a cohesionless soil. However, using this procedure calls for a lot of water. They can be compacted either in a dry condition or in a saturated state to attain the maximum dry density. {1}

4.2. ANGLE OF INTERNAL FRICTION:

The angle of internal friction affects how resistant soil mass grain particles are to sliding. The magnitude of the angle of internal friction is typically thought to vary with the density, or how tightly the particles are packed together, rather than with the normal pressure.

When compared to soils subjected to lower normal stresses, soils subjected to higher normal stresses will have lower moisture contents and higher bulk densities at failure, which could modify the angle of internal friction. Clay has an actual internal friction angle that is rarely zero and can reach 260.For granular soils, the angle of internal friction might range from 280 to 500. {1}

4.3. CAPILLARITY:

It is the soil's capacity to transfer moisture in all directions despite the effects of gravity. Capillary attraction causes water to ascend through soil pores.

The pressure that tends to push water into the soil determines the maximum theoretical height of capillary rise, and this force grows as the size of the soil particle decreases.

When a soil is wet, the capillary rise can be up to four or five times higher than when the soil is dry. The capillary rise of coarse gravel is zero, that of coarse sand is up to 30 cm, that of fine sand and soils is up to 1.2 m, while the capillary rise of dry sand is very low. Clays can exhibit capillary rises of up to 0.9 to 1.2 m, however they are of extremely little value when they are pure. {1}

4.4. PERMEABILITY:

The rate at which water flows through a soil under the influence of a hydraulic gradient is known as its permeability. Percolation is the term for the movement of moisture through the pores or gaps in the soil.

Pervious or permeable soils are those that are sufficiently porous to allow percolation to take place.

which do not allow water to get through are referred to as "impervious" or "impermeable." The head of water directly relates to the flow rate.

Permeability is a characteristic of the soil mass rather than of specific soil particles. Cohesive soil has a generally very low permeability. Understanding permeability is necessary for difficulties with seepage, drainage, and ground water as well as the pace at which structures settle on saturated soils.

4.5. SPECIFIC GRAVITY:

Specific Gravity is defined as the ratio of the given volume of soil solids at a given temperature to the weight of equal volume of distilled water at the temperature. This test was conducted according to IS: 2720 Part-3-1980.

4.6. ATTERBERG’S LIMITS

 1. Liquid Limit: It is the water content corresponding to the arbitrary limit between liquid and plastic state of consistency of soil. The liquid limit test was conducted according to IS: 2720 Part-4-1970.

2. Plastic Limit: It is the water content corresponding to the arbitrary limit between plastic and semi-solid states of the consistency of the soil. The plastic limit test was conducted on soil-mixtures passing through 425µ sieves as per IS: 2720 Part-5- 1970. {2}

4.7. STANDARD PROCTOR COMPACTION TEST:

This test's goal is to ascertain the link between moisture content and dry density. After that, the soil's ideal moisture content (OMC) and maximum dry density (MDD) were calculated using the Standard Proctors Test. According to IS: 2720 Part-7-1980, the soil sample for the Proctor's compaction test was prepared. {2}

4.8. PERMEABILITY TEST

Permeability of a soil is defined as the simplicity with which a fluid (often water) can pass through it. The rate of water flow across a unit cross-sectional area while flowing up a unit hydraulic gradient is what this term refers to. The head causing flow through the specimen stays constant during the test in a constant head permeaometer. The IS: 2720 Part-17-1986 constant head permeability test for soils was carried out. {2}

4.9. LABORATORY TESTING OF SOIL AND ROCK:

An essential component of a geotechnical study is laboratory testing. The ultimate goal of laboratory testing is to use repeatable procedures to improve the visual observations and field testing carried out as part of the subsurface field exploration program and to ascertain how the soil or rock will behave under the conditions imposed by Engineering Properties of Soil and Rock. The optimum laboratory program will offer enough information to finish a cost-effective design without requiring too many experiments or spending too much money. Testing might range from straightforward soil classification tests to intricate strength and deformation tests, depending on the project's problems. {10}

**5. APPLICATIONS OF ROCKS AND SOILS PROPERTIES:**

In the construction of roads and concrete, crushed or broken rocks are utilized as aggregates. Ballast for railways can also be made of crushed or broken rocks. Sand can be naturally replaced by stone screens. The primary component used in the production of cement and lime concrete is limestone.

Starting with creating or defining the geologic strata present at the location in issue, soil and rock characteristics are developed for geotechnical design objectives. Therefore, the particular geologic strata identified at the project site shall be the focus of the geotechnical design property assessment and final selection. A geologic strata is defined as having the same geologic depositional history, stress history, and degree of disturbance. Additionally, the density, source material, stress history, hydrogeology, and macrostructure are typically consistent throughout the stratum. Each stratum's characteristics must be compatible with its geologic depositional, stress, and macrostructural history.

Common engineering qualities including specific gravity, point load strength, compressive strength, tensile strength, shear strength, modulus, and durability are often determined by laboratory experiments. Visual inspection and description of discontinuities within the rock mass are used to determine the characteristics of the rock mass.

Final choice of property recognizing the variability stated in the preceding section, it is necessary to evaluate the potential effects of such variability (or uncertainty) on the design's level of safety, depending on the amount of variability estimated or measured. If this uncertainty is anticipated to have a major influence, parametric analysis must be performed or additional data may be gathered to assist reduce the uncertainty. It will not be possible to statistically combine all of these data to determine the most likely property value because the sources of data that could be taken into account include measured laboratory data, field test data, performance data (i.e., from back-analyses), and other prior experience with the geologic unit(s) in question.

This final evaluation and design property conclusion will require engineering judgment based on expertise, along with parametric analysis if necessary. After that, a choice must be taken regarding whether the final design value chosen should reflect the property's interpreted average value or a value that falls halfway between that value and the most conservative estimate of the property. But the need for design safety.

**Conclusions:**

Any material utilized in the building industry, whether it be natural, geological, man-made, or otherwise, must meet two fundamental criteria, namely strength and economy. The texture and mineral makeup of rocks contribute to their strength, although weathering has introduced some weaknesses. In comparison to rocks isolated from deeper parts of the earth's surface, those close or at the earth's surface are more likely to be subject to weathering. Because rocks are natural materials, their physical and mechanical characteristics can vary greatly.

* This course explores the fundamentals of geological and geotechnical knowledge applied to Civil engineering structures.
* To educate civil engineering students in rock engineering concepts and approaches in the Planning and design of Engineering Structures with construction materials.
* Have knowledge of design and construction to safely control rock and soil for engineering behaviour.
* It is a well-known fact that rocks plays a vital role in constructing the structures which are destined to be strong, appealing and economical.
* Engineering properties of rocks are very essential properties to be determined in every project of civil engineering, construction engineering and structural engineering.

OUTCOMES OF THE CHAPTER:

* Learn about different physical, mechanical and engineering properties of rocks to be used for different construction purposes.
* Understand the relationship between rocks and Soils Engineering structures.
* Understand Rocks and Soils properties, as they influence on civil engineering works.
* An ability to identify the various properties act on engineering problems.
* An ability to recognition the various properties act on engineering structures for Safety, Stability and Economy.

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