*TITLE OF THE CHAPTER:*

**ENGINEERING BEHAVIOUR (PROPERTIES) OF ROCKS AND SOILS**

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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 behavior (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 properties of rocks" refers to all of the characteristics of rocks that are important for engineering applications, whether they have been extracted from their natural beds 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.

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.

Rock mass properties are determined by visual examination and description of discontinuities within the rock mass. It should follow the suggested methodology of the International Society of Rock Mechanics (ISRM 1978), and how these discontinuities will affect the behavior of the rock mass when subjected to the proposed 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. PHYSICAL 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 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.

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

2.2. 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 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

TS=2P/µDL

D = diameter of the specimen

L = length of the specimen

2.3. 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/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. 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 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 mass .It may be obtained from the relationship.

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

2.6. PERMEABILITY:

It is a rock's ability to transfer water. Sandstones and limestones 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:

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. In every way, quartzites are the strongest.Examples include fresh quartzite, sandstone, and granite.

Carbonate rocks show a wide variation in their properties. A particular deposit of these rocks has to be tested by taking random representative samples before the stone is recommended for use in engineering construction of any importance. Presence of some minerals even in small quantites is to be viewed with caution while using in building stones. These minerals are mica, gypsum, sulphides, tremolite, flint and chert and clays. These destroy the inherent strength of the rock.

3.2. STRUCTURE AND TEXTURE:

The size, shape, and interrelationship of the mineral components in a rock are defined by its texture. whereas the overall development of the rock mass's large scale features is controlled by structure. The grain size of rocks can be coarse, medium, or fine.

The mutual arrangement of different mineral grains gives the type of rock its design pattern. The rock type displays a variety of architectural patterns, ranging from straightforward uniformly dispersed to weakly, moderately, and strongly foliated, and finally to severely gneissic.

Compared to rocks with coarse grains and inequigranular textures, rocks with fine grains and equigranular textures make better building stones. The reaction presented in the latter circumstances is of a complex and tends to behave as independent units when various compounds are exposed to the applied loads.

**4. GEOTECHNICAL PROPERTIES OF SOILS:**

Soil is composed primarily of minerals which are produced from parent material that is weathered or broken into small pieces. Plants and animals have important roles to play in soil.

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.

Generally various types of soils in our geographical country i.e. 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. {10}

4.1. COHESION:

It is the internal molecular attraction which resists the rupture or shear of a material. Cohesion is derived in the fine grained soils from the water films which bind together the individual particles in the soil mass.

Cohesion is the property of the fine grained soil with particle size below 0.002 mm. cohesion of a soil decreases as the moisture content increases. Cohesion is greater in well compacted clays and it is independent of the external load applied.

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 resistance in sliding of grain particles of a soil mass depends upon the angle of internal friction. It is usually considered that the value of the angle of internal friction is almost independent of the normal pressure but varies with the degree of packing of the particles, i.e. with the density.

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 ability of soil to transmit moisture in all directions regardless of any gravitational force. Water rises up through soil pores due to capillary attraction.

The maximum theoretical height of capillary rise depends upon the pressure which tends to force the water into the soil, and this force increases as the size of the soil particles 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:

Permeability of a soil is the rate at which water flows through it under action of hydraulic gradient. The passage of moisture through the inter-spaces or pores of the soil is called ‘percolation’.

Soils having porous enough for percolation to occur are termed ‘pervious’ or ‘permeable’.

which do not permit the passage of water are termed ‘impervious’ or ‘impermeable’. The rate of flow is directly proportional to the head of water.

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.

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.

ATTERBERG’S LIMITS

1. The liquid limit is the amount of water that corresponds to the arbitrary boundary between the liquid and plastic states of soil consistency. According to IS: 2720 Part-4-1970, the liquid limit test was performed.

2. Plastic Limit: This is the amount of water that corresponds to the arbitrary boundary between the plastic and semi-solid soil consistency phases. According to IS: 2720 Part-5–1970, the plastic limit test was performed on soil mixes that passed through 425 sieves. {2}

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}

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}

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 properties typically obtained from laboratory tests include specific gravity, point load strength, compressive strength, tensile strength, shear strength, modulus, and durability. Rock mass properties are determined by visual examination and description of discontinuities within 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 the impact of this uncertainty is likely to be significant, parametric analyses shall be conducted, or more data could be obtained to help reduce the uncertainty. Since the sources of data that could be considered may include measured laboratory data, field test data, performance data (i.e., from back-analyses), and other previous experience with the geologic unit(s) in question, it will not be possible to statistically combine all this data together to determine the most likely property value.

Engineering judgment based on experience, combined with parametric analyses as needed, will be needed to make this final assessment and design property determination. At that point, a decision must be made as to whether the final design value selected should reflect the interpreted average value for the property, or a value that is somewhere between the most likely average value and the most conservative estimate of the property. However, the desire for design safety must be balanced with the cost effectiveness and constructability of the design.

**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 and mechanical 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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