Rock Mechanics Properties

Introduction:-

Information collected by geologists and engineering geologists is in general not sufficient to predict the engineering behavior of rocks and rock masses. Tests need to be conducted to assess the response of rocks under a wide variety of disturbances such as static and dynamic loading, seepage and gravity and the effect of atmospheric conditions and applied temperatures. In

general, rock and rock mass properties can be divided into tow groups:

1. physical properties (porosity, permeability, etc.).
2. mechanical properties (deformability, strength).

Table 1. List of some physical and mechanical properties of rocks

PHYSICO MECHANICAL PROPERTIES	
Physical Properties	**Mechanical Properties**
Mineralogical composition - mineral structure, texture.	Elastic Modulus/ Deformation modulus and Poisson's ratio
Specific gravity, density, unit weight	Uniaxial compressive strength
Porosity, void ratio	Tensile strength
Moisture content, degree of saturation	Shear strength Properties
Permeability	Point load strength
Swelling properties	Rock hardness
Anisotropy	
Electrical properties	
Thermal properties	
Velocity of Elastic waves	
Durability	

Physical Properties of Rocks

The term petrophysics was created for physics of reservoir rocks. Petrophysics is suggested as the term pertaining to the physics of particular rock types. This subject is a study of the physical properties of rock which are related to the pore and fluid distribution . (Archie (1950), the pioneer in the application and quantification of rock physical relations to geosciences and petroleum engineering). Rocks in most cases are heterogeneous composite materials; only monomineralic rocks like rock salt or anhydrite contain only one mineral type. Heterogeneity becomes more contrasted if pores and fractures, filled with fluids, are present. This leads to a classification of rock properties into the following two main groups:

● Properties of direct interest for application: reservoir properties (porosity, saturation, permeability), geomechanical properties (deformation, strength), mineralogical characteristics (shale content, fractional mineral composition), content of substances of interest (ore content);

● Properties relevant to the various geophysical methods (elastic/seismic properties, density, electrical properties, nuclear properties, nuclear magnetic resonance (NMR) response).

"Properties of interest" are subjects of interpretation of geophysical data from surface and borehole measurement. This interpretation is a process of transformation of the second type into the first using additional input information. For the transformation, relationships are applied resulting from:

● empirical correlations (e.g., Archie's equation);

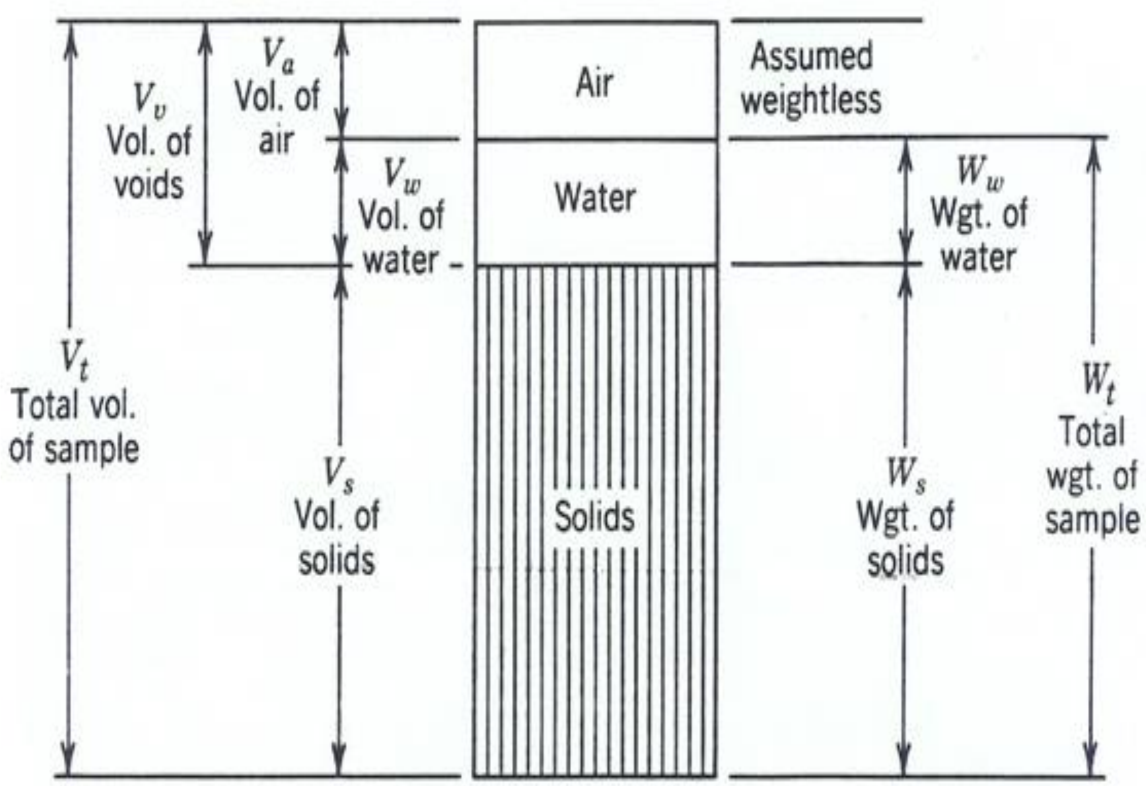


Figure 1. Volume – Weight Relations.

1- Density:-

is a measure of mass per unit volume and is a fundamental property for understanding weight-related phenomena. Density is a measure of how much mass is contained in a given volume. Granite has a density of around 2.7 g/cm^3, which means a cubic centimeter of granite weighs 2.7 grams. This makes it denser and heavier than something like pumice, which can float on water due to its low density.

• Question:

If a rock sample has a mass of 270 grams and occupies a volume of 100 cm^3, what is its density?

• Solution:

Density = Mass/Volume = 270 grams/100 cm^3 = 2.7 g/cm^3.

2- Porosity:-

It is the ratio of the volume of void spaces to the total volume. Porosity affects the fluid flow and storage characteristics of rocks. Limestone can have varying degrees of porosity depending on its formation. Some limestones can have high porosities which make them susceptible to dissolution and the formation of caves. Primary porosity can range from less than one percent in crystalline rocks like granite to over 55% in some soils.

• Question:

A rock has a total volume of 100 cm^3 and a pore volume of 20 cm^3. What is its porosity?

• Solution:

Porosity = (Pore Volume/Total Volume) x 100 = (20/100) x 100 = 20%.

3- Permeability:-

This property defines the ability of a rock to transmit fluids through its pore spaces.. It's directly related to the pore structure and connectivity. Sandstones with well-connected pore spaces may have high permeability, allowing fluids like oil or water to flow through them. Shales, on the other hand, typically have very low permeabilities, acting as barriers to fluid flow.

permeability can be expressed by the coefficient of conductivity *k* [$m.s^{-1}$], which means a discharge velocity of water flow in a rock under the action of a unit hydraulic gradient, usually expressed in meters per second

$$k = \frac{Q.\, l}{A.\, h.\, t} \quad (m/s)$$

where

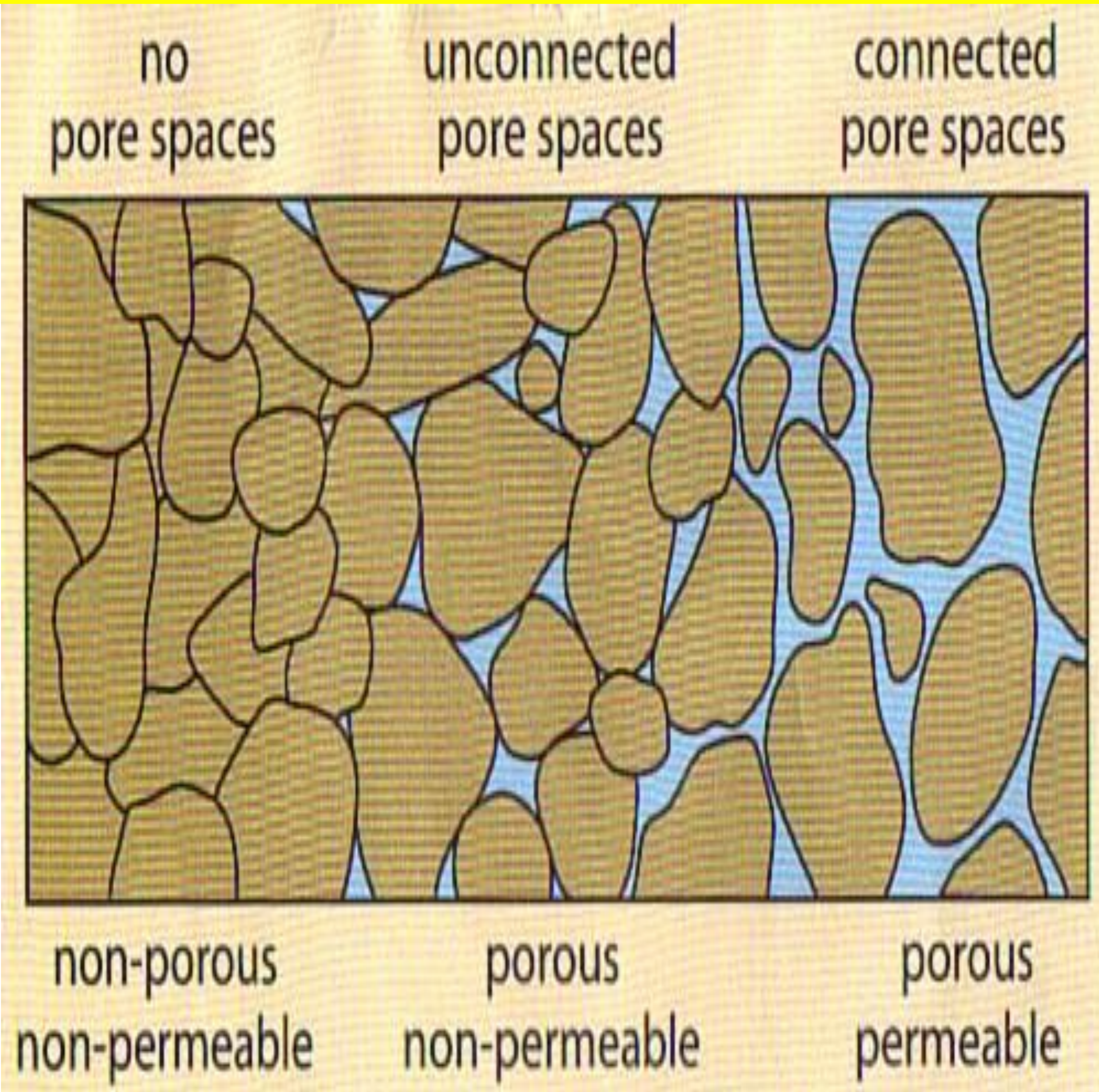
Q = is the volume of water leaking through the specimen during time t

L = is the height of the tested specimen

A = is the cross-section of the specimen

h = is the difference in the water pressure levels

t = is the period of measurement.



Question:

Why might a sandstone reservoir produce oil more efficiently than a shale reservoir?

Solution:

Sandstone typically has higher permeability than shale, meaning fluids can flow through it more easily.

4- Moisture Content:-

The water content of rock specimen can be calculated directly by dividing mass of pore water to mass of sample. It refers to the amount of water present in a rock, expressed as a percentage of its dry weight. After a heavy rainfall, a clay-rich soil might have a moisture content of 30%, meaning for every 100 grams of dry soil, there are 30 grams of water.

Question:

If a rock sample weighs 150 grams when wet and 120 grams when dry, what is its moisture content?

Solution:

$$\text{Moisture Content} = [(\text{Wet Weight} - \text{Dry Weight})/\text{Dry Weight}] \times 100 =$$

$$[(150-120)/120] \times 100 = 25\%.$$

When analyzing rock for engineering applications, understanding these properties is crucial. For instance, in tunnel construction, rocks with high porosity and permeability can pose challenges for water inflow. Similarly, in petroleum engineering, understanding rock permeability and porosity is crucial for evaluating reservoir potential.

These physical properties serve as a foundation upon which the mechanical properties (such as compressive strength, tensile strength, modulus of elasticity, Poisson's ratio, etc.) are built and understood.

Question:

A sample of rock has a porosity equal to 0.25 and a dry density equal to 2.22 g/cm^3 and has a total volume equal to $1cm^3$. Calculate the rock density while it is submerged.

Solution:

$$\rho_d = \frac{W_s}{V}$$

$$Ws = \rho_d \, . \, V = 2.22 \; g/cm^3 * 1 \; cm^3 = 2.22 \; g$$

The volume of the voids Vv = the volume of water into the voids = $\frac{W - W_s}{\text{water density } \rho_W}$

$$Vv = \frac{(W - W_s)\, g}{1\, g/cm^3} = = \frac{(W - W_s)\, g}{1\, g/cm^3} = (W - 2.22)\; cm^3$$

$$n = \frac{Vv}{V}$$

$$0.25 = \frac{(W - 2.22)\; cm^3}{1\; cm^3}$$

$$W = 0.25 + 2.22 = 2.47 \; g$$