How to practically estimate the petrophysical properties of rocks: A Proposal

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Abstract

The petrophysical properties of rocks are a strong and an effective indicator of the extent of the susceptibility of the rocks themselves to building and construction operations above and above them. As these tests are conclusive evidence that such rocks will not have a landslide or semi-collapse, and from here we focus in this scientific proposal paper on them practically in a manner of step-by-step, to make it easier for the specialist to understand the well. These properties are an assistant to the geologist and civil engineer in the field of work, as they work to provide actual numbers of the rocks, or in other words, the process of converting rocks into mere numbers that speak for themselves effectively and feasibly, such properties are sufficient.

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In this practical paper we highlight the properties of; ***Porosity***, ***Saturation Coefficient***, ***Moisture Content***, ***Water Absorption***, ***Specific Gravity***, ***Density***, we offer you a comprehensive scientific practical report that talks about the rocks and their susceptibility to building and construction operations.

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Introduction

Engineering geology is the practical application of geology in the field of engineering, and the goal of this process is to take into account and focus on geologic factors in various engineering works, as these factors affect the selection of the site, the design process, and the stage of engineering.

Engineering geologists provide geological and geotechnical advice and analyze and design structures based on human development and different types of structures in the field. The presence of an engineering geologist is necessary in projects that rely on an interaction between nature and origin, in order to assess the impact of land operations on human activities and facilities carried out by humans.

Engineering geology studies can be conducted during different stages of the project, as they can be conducted during the planning process, the environmental impact analysis process, the structural design process, or during construction operations in public and private projects, in addition to the stages of economic engineering.

Studies after the completion of the construction of the facility and during the judicial stages of the project. Geological work in engineering includes the following: geological hazard assessment, geotechnical engineering, material properties, landslide and tilt hazard, erosion, flooding, seismic studies, and water displacement.

The world of engineering geology specialists is primarily about interactions of the Earth's structure in architectural engineering construction sites and about investigating how geological terrestrial phenomena affect both structural structures and human activities.

One of the most important roles an engineering geologist plays is the study of landforms and ground processes to identify potential geological and associated man-made hazards that may have a significant impact on civil structures and human development. A background in geology provides an engineering geologist with an understanding of how the Earth works, which is critical to mitigating risks associated with the environment.

Many engineering geologists graduate with specialized training in soil mechanics, rock mechanics, geotechnology, drainage, hydrology and civil engineering. These two components of training engineering geologists provide a specific ability to understand and reduce the risks associated with Earth structure interactions.

The construction of large civil engineering projects requires knowledge of the geology of the respective selected area in which the construction will be completed or also helps to select the most geologically suitable area for the construction of projects.

The petrophysical properties of rocks are an important and vital indicator of the extent to which such rocks can be constructed and worked on. The most important of these is the examination of the porosity, permeability and water content of the rock and others, which we will focus on in this paper as a proposal, on the way of step-by-step model.

Tests Index

In this paper such a proposal type, we will focus upon the followings:

- Porosity.
- Saturation Coefficient.
- Moisture Content.
- Water Absorption.
- Specific Gravity.
- Density.

Tests Conditions

These aforementioned tests should be done by some eligible conditions:

- To make such tests, you should use regular rock samples, but on using non-regular ones, it’s must to remove the weathered surfaces, and make it to get out of your considering.
- The rock must be free of air inside it, by using a device to evacuate the air.

Apparatuses Needed

- Sensitive Electronic Balance (with 0.1 gm sensitivity).
- Iron Stand.
- Beakers (of volume: 120 – 1000).
- Drying Oven.
- Air-evacuation Device.
- Stopwatch.

Tests Scope

1- Porosity

Porosity is defined as a measure of the void spaces in a material, the material here in such a paper is a rock. But we should differentiate between porosity and permeability. The second-mentioned means to measure of the ability of a material (such as rocks, as well as a soil sample) to transmit fluids.

The rock may have a very high porosity, but if these pores were not connected to each other, it would not have proportional permeability. Similarly, another rock may have a few continuous and continuous cracks that allow easy fluid flow through them, but when the porosity is calculated, the rock does not appear to be very porous.

It depends upon followings:

- The porosity of igneous rocks, especially volcanic ones, depends on the speed of cooling. The slower the cooling conditions, the lower the porosity.
- But in the sedimentary rocks, it mainly depends upon the cementing materials, packing manner, geochemical processes evolved, and so o

Can be mathematically shown as a relation:

$$n = \frac{Vv}{Vd} * 100$$

Where: Vv is volume of voids – Vd is volume of whole rock – n is the porosity.

- ***How to estimate?***

  * The porosity can be found by the weight of a rock model when it is dry (W_d), its weight when it is saturated with water (W_s), and its weight when it is immersed in water (W_i), then we can find it by the following equation:

$$n\% = \frac{Ws - Wd}{Ws - Wi} * 100$$

  * There are two types of porosity:

    1- Partial Porosity.

    2- Total Porosity.

  * Partial Porosity:

    - Can be defined as the ratio between the total volume of the gaps (***voids***) in the rock model to the total volume of the rock model itself, without air-evacuating.

    - We take a regular or irregular rock model and put it in a drying oven, and continue to place it until a fixed weight is reached (W_d), then we immerse the model in water to a depth of 4 mm, and after 24 hours from the water reaching the surface of the rock model, we remove it, and then put it immersed in water for 48 hours, and this represents its weight saturated with water (W_s), and then we weigh the model while it is suspended with water (meaning the model with the water around it), and this represents the weight while it is submerged (W_i), than using the following equation:

$$n\ (Partail) = [\frac{(Ws - Wd)}{(Ws - Wi)}] * 100$$

* Total Porosity:

- Total porosity is defined as the ratio between the size of the gaps and pores in a rock model to the volume of the rock when it is completely empty and devoid of air.

- To calculate the total porosity, the rock model is dried in the drying oven until we reach a constant weight (W_d), then it is placed in the air-evacuating device and we continue to look at the device indicator until the rate of water pumping into it is fixed, and this usually happens after about 1.5 hours, then it is placed in water, then it is weighed in this case which represents (W_s), then it is weighed while suspended or immersed in water to give us (W_i), then we use the following equation:

$$n\ (Total) = \left[\frac{\frac{(Ws - Wi)}{\rho w}}{\frac{(Ws - Wi)}{\rho w}}\right] * 100$$

- But we have a similar term of ρw, and also equals to 1, so can be abbreviated and deleted from such an equation, so it looks:

$$n\ (Total) = [\frac{(Ws - Wd)}{(Ws - Wi)}] * 100$$

2- Saturation Coefficient

The saturation coefficient is the ratio between the partial porosity and the total porosity. It is normal for the freezing of water inside the joints, cracks or pores within the rocks to increase pressure and break those rocks into small pieces.

The successive process of freezing and melting widens the cracks between the rocks until they then break into separate blocks.

The effect of frost is especially concentrated in the areas of middle and high latitudes, as well as above high altitudes, where the prevailing temperature conditions allow the recurring process of freezing and thawing.

Sedimentary rocks are affected by this process more than igneous rocks because of the large number of joints, cracks and voids in them.

As a result of this process, the rocks turn into rocky debris with sharp sides. This rock debris remains in place if it is located over an area with a slight slope. The crumbs fall and gather at the bottom of the slopes, forming conical shapes known as ***talus***.

- ***How to estimate?***

  * So, when Saturation Coefficient is equal to that is less than 0.8, the rock is considered to be more resistant to the freezing-melting weathering-type processes. But on equality to 0.80 to 0.85, so such rocks may be semi-resistant. If the value of it is equal to that more than 0.85, so the rocks may be cracked and crushed by such processes.

$$Sc = [\frac{n\% \ (Partial)}{n\% \ (Total)}] * 100$$

3- Moisture Content

Moisture content can be defined as the ratio between the weight of water in the rock to the weight of the rock when it is dry. Or in other words; This means measuring the amount of water in the soil or rock unit. That is, the rock model is weighed in its natural state without being introduced to the drying oven, then dried and weighed while dry.

Moisture content is one the most important property that should be taken into account because it helps us identify some essential characteristics of the soil such as porosity, and permeability, and also tells us about the possibility of soil containing minerals.

- ***How to estimate?***

  * There are many methods for measuring moisture content, varying in the degree of ease and method used to perform it. We can measure the water content depending on the place of measurement, this means that we can detect moisture content either in the laboratory or in the field by using certain devices.

  * There is an important direct relationship between the moisture content and the resistance of the rock to the processes of dissolution, disintegration, weathering, and melting, as well as some other calculations of the rock such as tensile strength and

compressive resistance, as well as the modulus of elasticity, so we can induce it by the following equation (***laboratory***):

$$Mc = [\frac{Wn - Wd}{Wd}] * 100$$

Where: Wn is the weight of the rock normally in its normal case without showing to drying oven – Wd is the weight of the rock after showing to drying processes.

* Second, some methods for measuring moisture content in the field: We can measure moisture content in the field by using many methods, but especially, we will discuss measuring it using Capacitance or Time domain reflectometry (TDR) and Electrical Resistivity Tomography (ERT), Both methods use an electronic device, a digital plate, and some electrodes, and we can follow the following steps in the field:

- First, we fixed the electrodes in the ground by using a Hummer
- Turn on the device.
- An electrical current will pass through the ground, and then the ground will reflect the pulse again.
- After reflecting the wave, the device will receive it in the form of resistivity values.
- By using these values, we can detect the amount of water in the sample.
- We prefer to use ERT than using TDR because ERT is performed on large areas and gives very accurate data.

4- *Water Absorption*

Water absorption is defined as the ratio of the weight of the water absorbed by the whole rock in 48 hours to the weight of the dry rock itself.

The lower this percentage, the greater the resistance of the rock itself to the processes of freezing, dissolution, and various weathering factors, and so on.

- *How to estimate?*

* Weigh the rock sample when it’s a dry (W_d).

* Weigh the rock sample after the totally absorption of water in 48 hours (W_s).

* Subtract the two aforementioned values of weights ($W_d – W_s$), then we will be given the value of the water absorbed (W_a), so we can now use the following equation to estimate it:

$$W.A = \left[\frac{Ws - Wd}{Wd}\right] * 100$$

5- *Specific Gravity*

It is the ratio of the weight of the rock model to the weight of the same volume of water.

There are two types of specific weight; ***Apparent specific gravity*** is divided into two types: dry and saturated, and ***true specific gravity***.

- *How to estimate?*

* We should also measure the weight of the rock sample in dry, saturated, immersed cases respectively by using an electronic sensitive balance, to give; (W_d), (W_s), (W_i). As well as being aforementioned in the other above tests.

* Can apply the values into the following equation:

"Apparent Specific Gravity…

$$S.G\ (Apperant) = \left[\frac{Wd}{Ws - Wi}\right] * 100$$

Or…

$$S.G\ (Apperant) = \left[\frac{Ws}{Ws - Wi}\right] * 100$$

"True Specific Gravity…

$$S.G\ (Apperant) = \left[\frac{Wd}{Wd - Wi}\right] * 100$$

6- *Density*

Can be defined as a mass of a unit volume of a material substance, substance in such paper means a rock. It's unit: kg/m3 or gm/cm3, with an utmost famous law: $\rho = \frac{M}{V}$.

The density is the most important physical properties. Which widely used to identify pure substances and to characterize and estimate the composition of many kinds of mixtures.

It is also used to differentiate between original & artificial gemstones. And to know the bearing capacity of rock.

It depends upon:

- The mineral composition of the rock.
- Porosity.
- Number of voids and cracks within the rock.
- The amount (as volume) of the water inside the rock.

- ***How to estimate?***

 * By measure the mass of the rock. Now we determined the mass "**M**".

 * Then Fill a graduated cylinder with water till half.

 * After that drop the stone in it.

 * Then measure the difference between two cases before & after dropping the stone.

 * It is the volume "**V**" by mm^3 or cm^3 according to graduated cylinder which used:

(1 cm^3 = 103 mm^3), (1 m^3 = 106 cm^3)

 * Then by using the relation ($\rho = \frac{M}{V}$) determine the density "ρ".

• *Note:*

Density can be estimated by the means of weighting, and it's called a ***Density***, and it's defined as mass unit volumes, and symbolized as (ρ), with unit ($Kg/^3$), as well as the following:

1) The bulky density:

$$\rho\ (Bulk) = \left[\frac{\frac{(Mn)}{\rho w}}{\frac{(Ws - Wi)}{\rho w}}\right]$$

2) The dry density:

$$\rho\ (dry) = \left[\frac{Md}{\frac{(Ws - Wi)}{\rho w}}\right]$$

3) The saturated density:

$$\rho\ (saturated) = \left[\frac{Ms}{\frac{(Ws - Wi)}{\rho w}} \right]$$

Another type of it is ***the Unit weight Density***, and its unit is (KN/m^3), with symbol of (**γ**), and it's defined as weight unit volumes. And we can get moving between the weight and mass by the general relation between them ($\boldsymbol{W = m\ g}$), where the (W) is the weight of the rock sample, (m) is the mass of it, and (g) is the strength of the gravitational field (from 9.8 to 10 m/s^2). So, we can apply the values after their estimation in the three aforementioned laws; ***The Bulky Density***, ***The Dry Density***, and ***The Saturated Density***.

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