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Introduction

Praise be to Allah, who has guided and enabled us to publish the eleventh issue of the *Gharyan Journal of Technology*. We thank Him for this blessing. As we promised from the very beginning with the release of the first issue in 2016, we have continued our commitment to maintaining the journal's credibility by upholding academic integrity and relying on reviewers with sufficient expertise in their fields. This ensures that the works published in the journal are characterized by rigor and scientific methodology, without favoritism, bias, or leniency in publishing studies that lack scientific and research value. Although we receive a larger number of submissions, we publish only a limited number of research papers in each issue because many are declined by reviewers for not meeting scientific standards. We look forward to ensuring that the published studies contribute to offering proposals and developing effective solutions to the challenges faced by institutions such as companies, factories, hospitals, and other sectors.

Nations strive for progress and for attaining distinguished status through achieving growth, economic advancement, and a decent quality of life for their people. Scientific research is one of the most important means of reaching that noble goal. By employing research in innovative applications that serve humanity in general, this objective can be fulfilled. Developed countries allocate significant portions of their financial resources toward achieving this aim.

We fully recognize that working in peer-reviewed scientific journals is a demanding task, especially under the circumstances our country in particular—and the world in general—are experiencing. However, we accepted this challenge with full confidence that Allah will support us as we endeavor to present valuable work that benefits researchers, specialists, and interested readers. Our aim is for the journal to be one of the scientific platforms for researchers in a world witnessing an intense race in the realms of civilization, science, research, and technology. We strive diligently to carve out a worthy place for the journal, benefiting from the experiences

of those who preceded us in this long path. With God's permission, we hope that upcoming issues will be of even higher quality and that our journal will achieve an impact factor that reflects the value of the research it publishes. What further strengthens our determination and confidence is that the *Gharyan Journal of Technology* is issued by a well-established academic institution more than thirty years old, distinguished by its graduates who have joined numerous institutions across the country and have presented a positive image of the educational institution that prepared them.

The eleventh issue of the *Gharyan Journal of Technology* contains numerous research papers and scientific articles characterized by creativity and diversity, contributed by researchers from various educational institutions.

The Editorial Board renews its welcome to all researchers and contributors wishing to participate with scientific papers and innovative research in your journal, the *Gharyan Journal of Technology*, which seeks to achieve distinction among peer-reviewed scientific journals. We open the door to your suggestions, remarks, and constructive criticism, believing that such feedback is the best way to develop the journal, enhance its scientific value, and support its continuity.

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Researche Papers Written By English Language



Impact of Rock Properties on Density Estimation Using Core Data

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المخلص

تُعد كثافة المادة، والتي تُحسب بقسمة كتلتها على حجمها، إحدى خصائصها الأساسية. ومع ذلك، قد يكون من الصعب تحديد كثافة دقيقة لبعض أنواع الصخور. تسهم عوامل عديدة في هذا التحدي، بما في ذلك الحجم غير المنتظم للمادة، والمسامية، والمحتوى الرطوبي، والنفاذية، وغياب تعريف دقيق للكثافة. يتمثل التحدي الأساسي في حساب الكثافة الظاهرية (الكلية) للصخر في التقدير الدقيق للحجم الكلي لللب الصخري (العينة). لقد قمنا بدراسة أربع طرق شائعة لتحديد الكثافة الظاهرية للمادة. كما نظرنا في مشكلة تشبع اللب الصخري بالرطوبة. تم استخدام مجموعة متنوعة من سبعة أنواع مختلفة من الصخور في هذا الاختبار، تراوحت بين الحجر الرملي عالي النفاذية وخبث الأفران العالية (slag) الذي يحتوي على قدر كبير من الفراغات المسامية الداخلية، وصولاً إلى الجرانيت والدولوميت عاليي الصلابة (المتماسكين). لقد درسنا أربع نُهج (طرق) مختلفة تُستخدم بشكل متكرر لحساب الكثافة الظاهرية للمادة. شملت هذه التقنيات طريقة الفرجار (caliper method)، والغمر في الشمع، والغمر اللحظي في الماء، والغمر بالشمع المغلف بالانكماش (wax-shrink wrap) وُجد أن طريقة الغمر في الشمع هي الأكثر دقة بين التقنيات الأربع التي تمت دراستها. نتج هذا عن قدرة الشمع السائل على التوافق (الالتصاق) بشكل وثيق مع مسام سطح العينة، مما يوفر التقدير الأكثر دقة لحجم العينة. الكلمات المفتاحية: كثافة الصخور، المسامية، صخور المكنم الهيدروكربوني، الكثافة الظاهرية.

Abstract

A material's density, which is calculated by dividing its mass by its volume, is one of its fundamental characteristics. However, it might be challenging to determine a correct density for some rock types. Numerous factors contribute to this challenge, including the material's uneven volume, porosity, moisture content, permeability, and the absence of a precise definition of density.

Accurately estimating the overall volume of the rock core is the primary challenge in calculating its bulk density. We did not look only into four popular methods for determining a material's bulk density. But also looked at the problem of the rock core becoming saturated with moisture. A variety of seven distinct types of rock were used for this testing, ranging from extremely permeable sandstone and blast furnace slag with a significant amount of internal pore space to highly competent granite and

dolomites. In addition we looked at four distinct approaches that are frequently used to calculate a material's bulk density.

These techniques included the caliper method, wax immersion, instantaneous water immersion, and wax-shrink wrap immersion. The wax-immersion method was found to be the most accurate of the four techniques examined. This resulted from the liquid waxes' capacity to closely conform to the sample's surface pores, providing the most precise estimation of the sample's volume.

Key words: density rock, porosity, hydrocarbon reservoir rock, bulk density.

Introduction

Density, which is calculated by dividing mass by volume, is a fundamental characteristic of a substance. Although the definition is simple, it can be challenging to determine a material's density in some situations. [1] For instance, items made up of irregular shapes that are highly broken and composed of numerous fragments might make it challenging to calculate an exact volume and, consequently, the density. Most of the time, determining the object's volume rather than its mass presents a major obstacle to establishing an exact density.

The mass term in determining a material's density is simple, but the volume term can be challenging. For instance, the basic geometric equation for a cylinder can be used to calculate the volume of a rock core that has been cut on both ends to form a cylinder. Once the mass or weight has been established, the diameter and length of the core can be measured with a caliper, and a density can be computed. [2] However, this is predicated on the very general assumption that the rock's surface is flawlessly smooth and devoid of any flaws or voids. This assumption is incorrect for the majority of materials because nearly all samples will have some surface irregularity, which can change the volume when thinking it is a cylinder. Certain materials may have smooth surfaces with few voids along the surface, but other materials with rough surfaces or deeply seated surface pores may have an impact on the volume calculation, which in turn may have an impact on how accurately a material's density is determined. [3]

Bulk density is defined as a sample's density that takes into account both the soil's solid particle percentage and its internal and surface pore space. [4]. Although there are now a number of techniques for figuring out a sample's bulk density, they might not work across a broad variety of sample sizes, porosities, and permeabilities. This idea is distinct from particle density, also known as specific gravity, which is the density of the substance's constituent particles excluding the sample's voids.

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The following figures illustrate the distinction between bulk density and particle density (specific gravity). A material made of solids is depicted in Figure 1 [5], where the void space is divided into an inter-particle void volume and a "surface" pore volume. Only the material's internal pores are taken into account when calculating bulk density. As a result, the volume calculation of bulk density does not account for the material's surface pores.

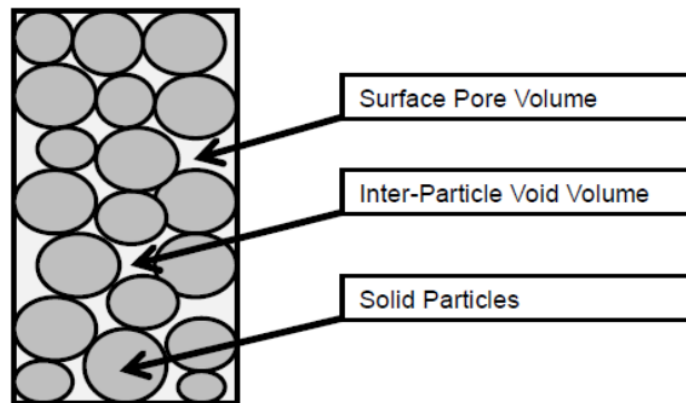


Figure 1 a sample showing the difference between the different void volumes [5]

Only the solid half of the sample is represented by the particle density, which is directly correlated with a material's specific gravity. Consequently, the voids in the material are not included in the particle density, which is calculated by dividing the particle mass by the particle volume. Figure 2 illustrates this. [6]

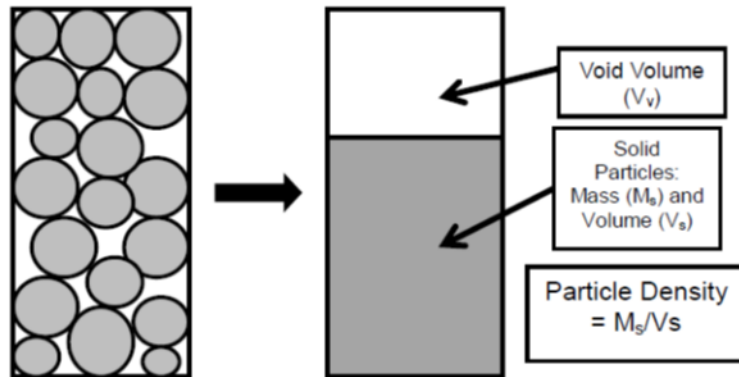


Figure 2 a particle density of a core sample [6]

When working with aggregates, the problem of precise bulk density, particle density, and absorption measurements may also arise. If the specifications of the aggregate used in a concrete mix are not determined correctly, it can lead to issues with the mix or the use of the incorrect aggregate, which can result in improper concrete attributes including a loss in concrete strength. Additionally, determining the mass of aggregate based on a volumetric measurement might have major issues if the bulk density of the material is not calculated correctly. There are several automated and manual methods for determining both the bulk and particle density of a material. For example, an automated helium pycnometer, which uses helium gas to calculate a material's volume; it can also be used to calculate a material's specific gravity or particle density [7]. Although they are sometimes restricted to smaller sample sizes of 1000 cm³ or less, helium pycnometers are commonly employed in industry. The density of a particle can be determined with extreme accuracy using the helium pycnometer.

Additionally, very accurate estimates of a material's bulk density can be obtained via automated bulk density devices. The problem with both of these techniques, however, is that the equipment's size restrictions make it challenging to gauge the density of normal rock core produced by routine drilling operations. Usually measuring one to two inches in diameter and varying in length, typical rock cores cannot typically be analyzed without being broken down to fit into the instruments. [8]

Rock cores from mining exploration projects can be used for a variety of purposes, such as determining the strength, metallurgy, and mineral content of the ore. Additionally, it is usually necessary to preserve a portion of the core for archiving purposes. Quartering is the process of cutting the core into quarters in order to

achieve this. Generally speaking, a rock core's bulk density needs to be ascertained before the core is quartered since it becomes a crucial metric for figuring out how much ore is in the body. Because the rock core is swiftly cut and shipped out for investigation once it is obtained, the density determination must be completed promptly. [9]

The following are some of the problems with the techniques used to determine the bulk density of rock core. First, if further testing is required later on, the procedure must not harm the core. Second, the core must not be contaminated by the process. This is crucial to the mining exploration sector, but it is less significant in the aggregate sector. Determining the mineral composition of a sample requires the ability to assay it at a later time. Third, the technique must be adaptable to a broad range of rock types and offer a rapid and cost-effective way to determine the density of the rock core. Fourthly, The technique must yield a precise result, be repeatable, and not rely on the operator. [10].

The primary techniques for calculating the bulk density of rock core are still done by hand, and only a small number of these techniques may be applied to larger, irregular rock fragments.

There are no thorough guidelines to adhere to that deal with the possible problems in determining an accurate bulk density. For instance, a sample with a lot of surface pores will require a different treatment than a sample with little to no open pore space. Similarly, a sample that is highly permeable will need different testing than a rock that is nearly impermeable.

Methodology

Seven different types of rocks were used to investigate four methods for determining the bulk density of rock core, as well as the particle density (specific gravity) and the surface-saturated-dry density, which are used in the design of a concrete mix. The rocks were chosen to help represent a wide range of porosities, pore structures, permeability, and hardness.

The following four techniques were assessed for determining the bulk density of rock core:

- (1) caliper method
- (2) instantaneous water immersion
- (3) wax immersion

(4) wax-shrink wrap immersion

Preparation and Description of Rock Types

Making sure that a wide range of geologic origins, porosities, hardness, and permeability were represented was one of the main objectives while choosing the rocks for this project.

A 1 7/8-inch diameter was used to core the samples. By securely fastening the rock to the drill press, care was taken to reduce the likelihood of any lateral movement of the rock in order to help limit any variances in the diameter of the cores. Additionally, bits were routinely examined to make sure there was enough cutting edge left to readily core the rock. After that, a rock saw was used to cut the cores into a 2:1 ratio. It was sometimes impossible to achieve a true 2:1 ratio. One explanation for this was that the original rock from which the core was extracted was either too thin to yield a core of the right length or broke into multiple pieces during the cutting or coring procedure. The sample was made from the largest length of core that remained in both situations. Following testing and cutting, the samples were dried in an oven set at 110°C for 24 hours (\pm 4 hours). This was done to guarantee that all calculated densities were dry densities and to exclude any retained moisture in the sample.

Results and Discussion

The bulk density test results by kind of rock are shown in Tables 4-1 through 4-7 below. The given value is the mean of the caliper technique, instantaneous water immersion, wax immersion, and wax-shrink wrap immersion tests.

The Wax-Immersion method was found to be the most accurate of the four methods tested for bulk density testing. This technique is effective because the wax coating closes off the rock's surface pores, preventing water from penetrating and absorbing into the rock sample. Additionally, the Wax-Immersion process can be used with ease to materials that are extremely broken, fragmented, or prone to disintegration.

It should be mentioned, nonetheless, that the Instantaneous Water Immersion approach would be equally accurate for some rock types whose interior structure is highly impermeable or lacks considerable surface pores. For instance, because sandstone is a highly permeable rock type, it was challenging to get an accurate figure for the suspended weight during the Instantaneous Water Immersion trial because the scale kept recording a larger weight as the water seeped into the sample. These made

it extremely difficult to determine the bulk density of the sandstone. Nevertheless, the results for the Wax Immersion method and the Instantaneous Water Immersion method were nearly equal when examining the granite and brack dolomite samples, both of which had significantly lower porosity and permeability.

It is evident from looking at Table 4-1 and comparing the Wax Immersion and Water Immersion columns that the two bulk densities are typically different by roughly 0.03 g/cm³. The two values coincide in other more competent rock types, like granites and some of the Various Carbonates section. This is because there are no surface pores and therefore low permeability and porosity values. Due to the erroneous suspended weight measurement caused by water seeping into the rock cores, the Water Immersion method produced a density that was lower than the real bulk density value in nearly every kind of rock examined.

The key limitation of the Wax-Shrink wrap Immersion method is how hard it is to get rid of all the trapped air between the rock's surface and the shrink wrap while it is being wrapped. It was feasible to obtain a reasonably secure wrap on rocks without substantial surface pores, such granite or sandstones. However, the overall error in determining the bulk density of the air and water-cooled slag samples increased with the depth and size of the surface pores. This was partly because the plastic could not be used to completely enclose the pores' inside. For several of the cores without substantial surface holes, The Caliper technique yielded highly accurate results. This contrast was particularly noticeable for the blast slag samples, which did have relatively big holes. The results were extremely accurate and typically within 0.01 g/cm³ of one another in other more massive rock types, such granite.

Table 4-1 bulk density results for Rock Type (Granite)

Sample no	Bulk Density Results by Method (g/cm ³)			
	Caliper	Instantaneous Water Immersion	Wax Immersion Method	Wax-Shrink Wrap Immersion
Granite 1	2.65	2.64	2.66	2.62
Sample no	Caliper	Instantaneous Water Immersion	Wax Immersion Method	Wax-Shrink Wrap Immersion
Granite 2	2.64	2.63	2.66	2.60
Granite 3	2.64	2.64	2.64	2.58

Table 4-2 bulk density results for Rock Type (brack Dolomite)

Sample no	Bulk Density Results by (g/cm ³)			
	Caliper	Instantaneous Water Immersion	Wax Immersion Method	Wax-Shrink Wrap Immersion
brack Dolomite 1	2.66	2.65	2.69	2.63
brack Dolomite 2	2.66	2.72	2.71	2.65
brack Dolomite 3	2.73	2.70	2.75	2.68

Table 4-3 bulk density results for Rock Type (hamada Dolomite)

Sample no	Bulk Density Results by (g/cm ³)			
	Caliper	Instantaneous Water Immersion	Wax Immersion Method	Wax-Shrink Wrap Immersion
hamada Dolomite 1	2.67	2.61	2.69	2.46
hamada Dolomite 2	2.77	2.77	2.74	2.61
hamada Dolomite 3	2.44	2.45	2.44	2.50

Table 4-4 bulk density results for Rock Type (Dolostone)

Sample no	Bulk Density Results by (g/cm ³)			
	Caliper	Instantaneous Water Immersion	Wax Immersion Method	Wax-Shrink Wrap Immersion
Dolostone 1	2.56	2.78	2.78	2.64
Dolostone 2	2.73	2.80	2.77	2.67
Dolostone 2	2.70	2.74	2.74	2.67

Table 4-5 bulk density results for Rock Type (limestone)

Sample no	Bulk Density Results by Method (g/cm ³)			
	Caliper	Instantaneous Water Immersion	Wax Immersion Method	Wax-Shrink Wrap Immersion
Limestone 1	2.29	2.40	2.35	2.22
Limestone 2	2.32	2.45	2.37	2.27
Limestone 3	2.28	2.40	2.35	2.26

Table 4-6 bulk density results for Rock Type (Sandstone)

Sample no	Bulk Density Results by Method (g/cm ³)			
	Caliper	Instantaneous Water Immersion	Wax Immersion Method	Wax-Shrink Wrap Immersion
Sandstone 1	2.11	2.18	2.14	2.06
Sandstone 2	2.11	2.18	2.15	2.10
Sandstone 3	2.10	2.17	2.13	2.03

Table 4-7 bulk density results for Rock Type (Calcite)

Sample no	Bulk Density Results by Method (g/cm ³)			
	Caliper	Instantaneous Water Immersion	Wax Immersion Method	Wax-Shrink Wrap Immersion
Calcite 1	2.11	2.27	2.20	2.09
Calcite 2	2.16	2.37	2.27	2.12
Calcite 3	2.07	2.31	2.17	2.02

Tables 4-8 to 4-14 show the results of the two particle density methods tested

Table 4-8 particle density results for Rock Type Granite

Sample	Helium Pycnometer Results (g/cm ³)	Saturated Surface Dry Method (g/cm ³)
Granite 1	2.64	2.64
Granite 2	2.64	2.65
Granite 3	2.64	2.64

Table 4-9 particle density results for Rock Type brack Dolomite,

Sample	Helium Pycnometer Results (g/cm ³)	Saturated Surface Dry Method (g/cm ³)
brack Dolomite 1	2.68	2.68
brack Dolomite 2	2.68	2.70
brack Dolomite 3	2.75	2.75

Table 4-10 particle density results for Rock Type hamada Dolomite

Sample	Helium Pycnometer Results (g/cm ³)	Saturated Surface Dry Method (g/cm ³)
hamada Dolomite 1	2.80	2.68
hamada Dolomite 2	2.80	2.74
hamada Dolomite 3	2.81	2.71

Table 4-11 particle density results for Rock Type Dolostone

Sample	Helium Pycnometer Results (g/cm ³)	Saturated Surface Dry Method (g/cm ³)
Dolostone 1	2.83	2.77
Dolostone 2	2.83	2.78
Dolostone 3	2.83	2.37

Table 4-12 particle density results for Rock Type limestone

Sample	Helium Pycnometer Results (g/cm ³)	Saturated Surface Dry Method (g/cm ³)
Limestone 1	2.93	2.39
Limestone 2	2.96	2.32
Limestone 3	2.95	2.30

Table 4-13 particle density results for Rock Type Sandstone

Sample	Helium Pycnometer Results (g/cm ³)	Saturated Surface Dry Method (g/cm ³)
Sandstone 1	2.65	2.21
Sandstone 2	2.64	2.13
Sandstone 3	2.65	2.13

Table 4-14 particle density results for Rock Type Calcite

Sample	Helium Pycnometer Results (g/cm ³)	Saturated Surface Dry Method (g/cm ³)
Calcite 1	2.76	2.19
Calcite 2	2.86	2.22
Calcite 3	2.95	2.14

The results of testing during a 24-hour period are shown in the following graphs. The core samples were fully submerged in water during this time, and every one to four hours they were taken out and weighed to determine how much water weight had been added.

Each sample should ideally reach a point at which its weight is no longer rising. This will take place throughout the course of twenty-four hours. The red line, which represents the material's real porosity, is also displayed on the Figures (3) to Figures (16) with different lithology. The bulk density from the Wax Immersion technique and the particle density from the Helium Pycnometer were used to compute this as shown in table 4-8 to 4-14.

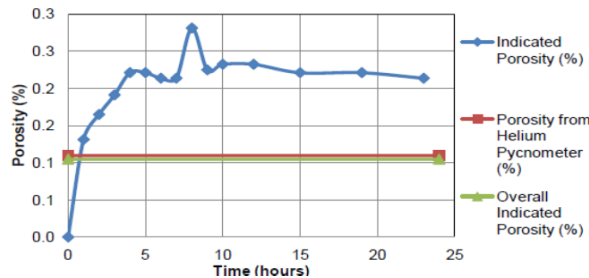


Figure 3 Indicated Porosity Graph for sample number Granite 1

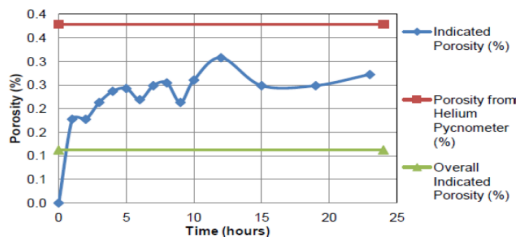


Figure 4 Indicated Porosity Graph for sample Granite 2

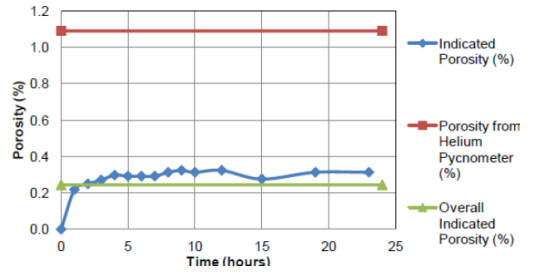


Figure 5 Indicated Porosity Graph for sample number brack Dolomite 1

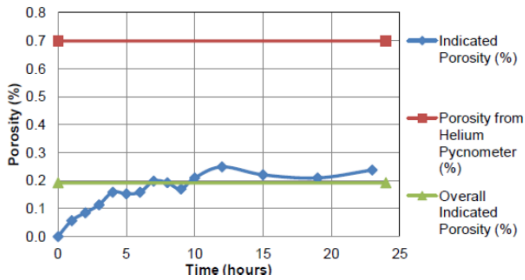


Figure 6 Indicated Porosity Graph for sample number brack Dolomite 2

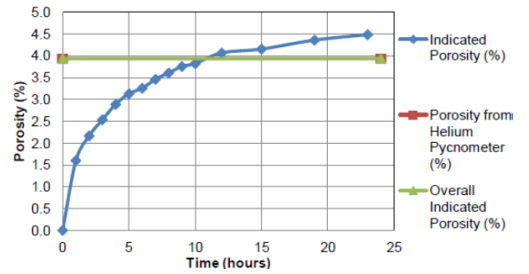


Figure 7 Indicated Porosity Graph for sample number Hamada Dolomite 1

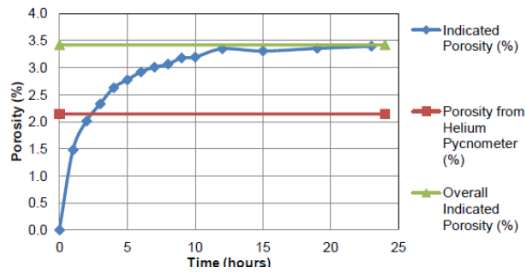


Figure 8 Indicated Porosity Graph for sample number Hamada Dolomite 2

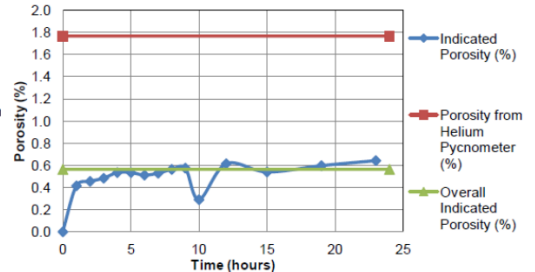


Figure 9 Indicated Porosity Graph for sample number Dolostone 1

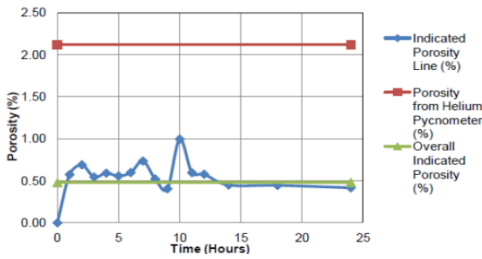


Figure 10 Indicated Porosity Graph for sample number Dolostone 2

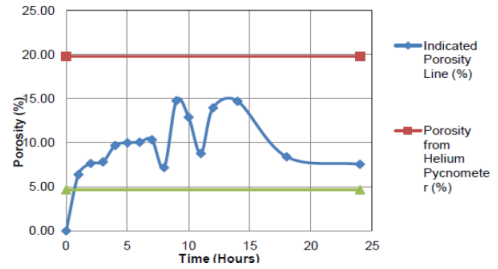


Figure 11 Indicated Porosity Graph for sample number Limestone 1

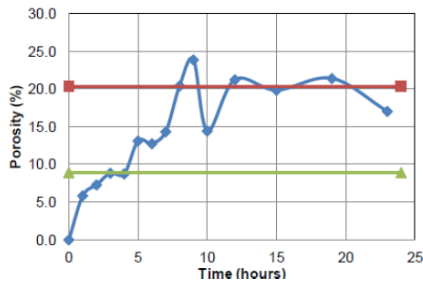


Figure 12 Indicated Porosity Graph for sample number Limestone 2

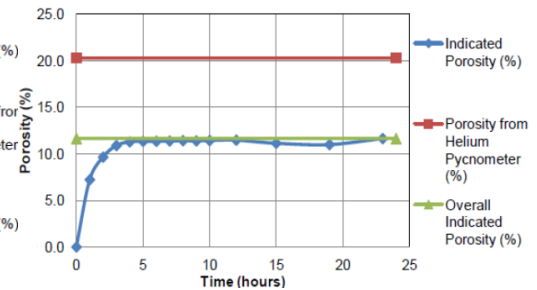


Figure 13 Indicated Porosity Graph for sample number Sandstone 1

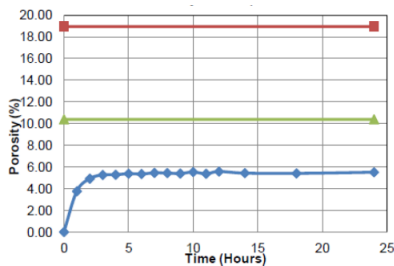


Figure 14 Indicated Porosity Graph for sample number Sandstone 2

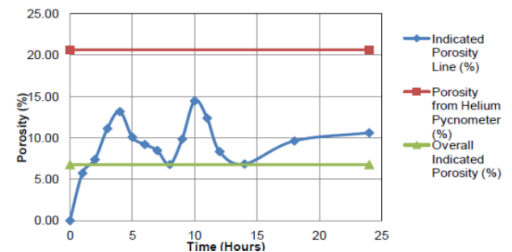


Figure 15 Indicated Porosity Graph for sample number Calcite 1

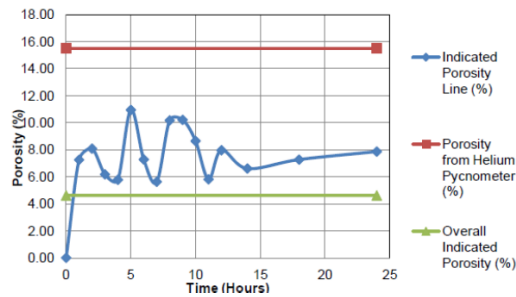


Figure 16 Indicated Porosity Graph for sample number Calcite 2

Conclusion

Density seems like a simple concept to comprehend. In its most basic form, it is a pretty easy-to-understand notion. Just divide an object's mass by its volume. But things may rapidly get complicated when you start adding other elements like porosity, permeability, absorption rates, pore diameters, and the processes that create the samples themselves. Accurately determining a sample's volume is essential because most items in the field of geotechnical engineering do not fall into ideal geometric shapes.

When that amount is multiplied to reflect a significant mass or volume, inaccuracies as small as 0.05 g/cm^3 can often result in broad errors. The biggest obstacle to any of these measurements, out of all the methods explored, is the constant presence of human error. This is particularly true when numbers need to be chosen fast, like in water immersion tests when the submerged weight needs to be determined before the water starts to penetrate the sample.

All things considered, the Wax Immersion method is the suggested approach for figuring out bulk density. The question of whether there is another viable technique for determining particle density should be investigated further.

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