JOURNAL OF SUSTAINABLE UNDERGROUND EXPLORATION
e-ISSN: 2821-2851

Vol. 3 No. 2 (2023) 7-12
https://publisher.uthm.edu.my/ojs/index.php/j-sue

J-SUE

A Comparative Analysis of Mechanical Properties Between Granite and Basalt Rock Core Samples

Hamizah Zainil[1], Aziman Madun[1*], Melvern Goh Keat Heng[1], Muhammad Aminuddin Khalid[1]

[1] *Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA*

*Corresponding Author: aziman@uthm.edu.my
DOI: https://doi.org/10.30880/jsue.2023.03.02.002

Article Info

Received: 23 October 2023
Accepted: 18 December 2023
Available online: 24 December 2023

Keywords

Compressive strength, tensile, UCS, Brazilian, PUNDIT, granite, basalt, rock, density

Abstract

Structural failure occurs when a load-bearing component of a structure fails to support and transfer loads to another element, leading to a breakdown in the performance of the materials in that structural component. The potential for structural failure is influenced by various variables, emphasizing the importance of understanding the behavior and parameters specific to rocks and soils in construction. In order to prevent failures in construction, engineers must possess a fundamental geological knowledge of rocks during the design process, recognizing the limitations of this construction material. Consequently, it is imperative to conduct tests to determine the precise strength of the rock being utilized. This study focused on granite and basalt, employing the Portable Ultrasonic Non-Destructive Digital Indicating (PUNDIT) test, Uniaxial Compressive Strength (UCS) test, and Brazilian test. The selected rock samples adhered to a diameter and thickness ratio of 1:2 or 2:1, depending on the specific test to be conducted. Density, compressive strength, and tensile strength of the rock samples were evaluated following the guidelines provided by the American Society for Testing and Materials (ASTM). The findings revealed that basalt exhibited higher density, compressive strength, and tensile strength compared to granite, with variations in results ranging from 13% to 40%.

1. Introduction

Rock and soil play essential roles, especially as construction materials. Engineers must deal with rock and soil during various stages, including roads, tunnels, or dams. From the earliest planning process until the execution, engineers should study and know the basic knowledge of rocks, such as physical properties, strength, and behavior of rock under various conditions. From the site's investigations, the foundation's design, and construction to the construction of superstructure, rocks and soils are involved [1]. Hence, it shows that engineers must have basic geological knowledge of rocks to understand this construction material's limitation.

Rock is naturally occurring solid, cohesive aggregates of one or more minerals [2]. Rocks are classified into three classes based on their geological genesis and processes: igneous, sedimentary, and metamorphic. These three types of rocks were categorised depending on their chemical, how the rock formed, and the formation environment. Compared to rock, the behaviour of artificial material like concrete is relatively more uniform, and its strength could be easily approximated from the designed mix. Rocks can be utilized in engineering structures as fill and reclamation material in construction such as cut slopes, foundations, and underground excavation.

Although rock strength and material properties are not expressed in rock names and classifications (as defined by geology), these factors are crucial for designing rock structures and for predicting potential issues during civil engineering construction (e.g. method of excavation and stabilization) [1]. Rock testing is an essential issue in rock mechanics.

Laboratory and in-situ testing are the two categories whereby the rocks are tested. The tests are conducted to evaluate the rock's basic, index, and engineering properties. Laboratory testing can be performed under uniaxial and triaxial compression. Indirect testing and direct testing are the types of testing methods. The Portable Ultrasonic Non-Destructive Digital Indicating (PUNDIT) test and the Brazilian test are two of the often-used tests in this assessment for indirect tensile tests. Other than the compression test, rock compressive strength can also be determined using the non-destructive testing (NDT) methods. Ultrasonic Pulse Velocity is the most popular of NDT method used to determine the strength of concrete. This is due to their relatively low cost and simplicity in handling the test. Although the non-destructive testing (NDT) results are much quicker than the destructive methods, they are more of an approximation than exact compressive strength values [3].

This research aims to determine the compressive strength and tensile strength using Brazilian, Uniaxial Compressive Strength (UCS) and PUNDIT tests and compare the properties and strength of granite and basalt. Compressive strength was determined using the UCS test while tensile strength was determined using the Brazilian test.

2. Materials and Method

This section will describe how the rock samples were carefully prepared for testing. The sample preparation process involved ensuring their shape and complete dryness, and the coring technique was employed to collect undisturbed samples representative of the in-situ material. Subsequently, experiments were conducted to measure the velocity, compressive strength, and tensile strength of these rock samples using various testing methods, including the PUNDIT test, UCS test, and Brazilian test.

2.1 Sample Preparation

In this study, two types of rock samples, granite, and basalt, were utilized. Before testing, it was essential that the rock samples were in good shape and completely dry. These samples were sourced from the site investigation or exploration conducted by Preston GeoCEM Sdn.Bhd, originating from two distinct locations. Specifically, the granite samples were obtained from Kulai, and the basalt samples were sourced from Segamat. Both rocks were acquired through the coring test sample technique, which aims to collect undisturbed and intact samples representative of the material in its natural setting.

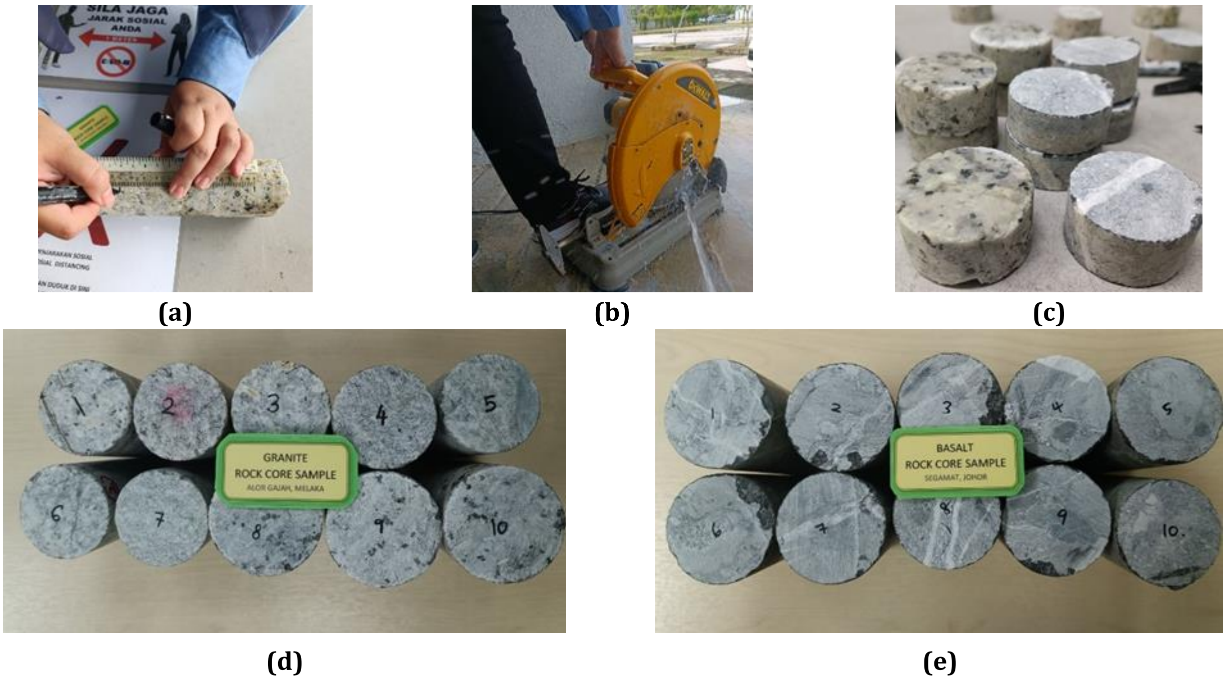

Fig. 1 *Process of preparing samples (a) Marking the sample; (b) Cut the sample using a cutter machine; (c) Samples of granite and basalt for Brazilian test; (d) Ten samples of granite for UCS test; (e) Ten samples of basalt for UCS test*

The company-supplied samples varied in lengths and diameters. In this study, the critical factor was not the diameter or length of the samples, but rather meeting the minimum requirements of a 1:2 or 2:1 ratio, depending on the specific test criteria. Consequently, accurate dimension data played a crucial role in subsequent calculations. The sample preparation process, as illustrated in Fig. 1, involved measuring the diameter, marking the samples, cutting them to a specified thickness using a Dewalt 355mm 220W Abrasive Chop Saw, and finally, organizing and labelling each sample.

2.2 Experiment Testing

The rock samples were measured on the velocity, compressive strength, and tensile strength.

2.2.1 Velocity

The PUNDIT test, commonly employed for rock and concrete, is an indirect and cost-effective method [1]. The pulse velocity in a material relies on its density and elastic properties, which, in turn, are associated with the material's quality and strength. In this study, the PUNDIT test serves as a reliable and accurate approach to determine the P-wave velocity in the rock samples [4]. Fig. 2 illustrates the equipment and arrangements employed in the PUNDIT test.

Fig. 2 *The arrangement of PUNDIT test*

2.2.2 Compressive Strength

Compressive strength, assessed through the UCS test, is a mechanical evaluation that measures material strength. A constant vertical normal stress was applied to the horizontal circular cross-sections of a cylindrical sample until failure, without confining pressure. This straightforward test [5] utilized average sample testing to determine the rock's compressive strength, calculated as per Equation 1. Fig. 3 illustrates the equipment of compression machine.

$$Compressive\ strength = \frac{Force\ (kN)}{Area\ (m^2)} \tag{1}$$

Fig. 3 *Compression machine*

2.2.3 Tensile Strength

Determining the direct tensile strength and deformability of rocks was challenging both in the laboratory and field settings. Given the difficulties associated with direct tensile tests, alternative methods, such as the Brazilian test [6], have been proposed. These indirect approaches utilize far-field compression to induce tensile stress in the samples, offering a more manageable, cost-effective, and widely employed means of assessing the rock's tensile strength through instrumentation compared to direct tests [7]. The tensile strength of rocks is calculated using Equation 2. Fig. 4 illustrates the equipment Brazilian test.

$$Tensile\ strength = \frac{Force\ (kN)}{Area\left(m^2\right)} \tag{2}$$

Fig. 4 *Brazilian test equipment*

3. Result and Discussion

This section presents the data and results derived from laboratory tests conducted on the materials utilized in this study, encompassing two distinct rock types: granite and basalt. Sample preparations adhered to ASTM D7012 standards and were meticulously carried out in the laboratory using a comprehensive array of equipment to ensure sample suitability prior to testing. Multiple data collection iterations were performed to ascertain and derive average values for enhanced result accuracy. The analyzed data is presented in tabular form for comparative assessment of results between the two types of samples.

3.1 Velocity

Table 1 displays the average velocity (m/s) for both granite and basalt. PUNDIT results indicate that, in the first test, granite samples exhibited a lower average value (5339.1 m/s) compared to basalt (6372.4 m/s), resulting in a 16.2% difference. In the subsequent test (test 2), granite again recorded a lower average velocity at 4657.2 m/s, whereas basalt displayed a higher value of 5407.2 m/s, reflecting a 13.9% difference.

Table 1 *Average velocity for granite and basalt*

Name of Samples	Average Velocity (m/s)	Name of Samples	Average Velocity (m/s)
		Test 1	
G1	5870.0	B1	6319.6
G2	5655.2	B2	6391.0
G3	5745.2	B3	6401.0
G4	5130.0	B4	6501.6
G5	5330.8	B5	6524.0
G6	5758.6	B6	6450.0
G7	5632.4	B7	6141.4
G8	4507.8	B8	6402.0
G9	5740.0	B9	6214.8
G10	4020.8	B10	6379.0
Average	5339.1	Average	6372.4
		Test 2	
G11	5897.0	B11	6897.0
G12	3980.4	B12	6176.0
G13	5897.0	B13	6176.0
G14	4230.8	B14	3898.0
G15	3281.0	B15	3889.0
Average	4657.2	Average	5407.2

3.2 Compressive Strength

Referring to Table 2, granite exhibited a range of compressive strength values from 12.7 MPa (lowest) to 87.2 MPa (highest), whereas basalt showed values ranging from 10.0 MPa (lowest) to 100.6 MPa (highest). The average compressive strength for granite was 43.1 MPa, while for basalt, it was 53.2 MPa. Consequently, these findings indicate that basalt possesses a higher compressive strength than granite, with a notable 19.1% difference.

Table 2 *Compressive strength of granite and basalt*

Name of Samples	Density (kN/m^3)	Average Velocity (m/s)	Uniaxial Compression Strength (MPa)
G1	21.508	5870.0	87.2
G2	22.795	5655.2	57.3
G3	22.563	5745.2	61.8
G4	22.007	5130.0	12.7
G5	23.214	5330.8	19.6
G6	22.634	5758.6	15.7
G7	21.837	5632.4	51.4
G8	20.807	4507.8	41.2
G9	23.136	5740.0	39.9
G10	23.279	4020.8	43.7
Average	22.378	5339.1	43.1
B1	23.284	6319.6	10.0
B2	23.544	6391.0	18.9
B3	23.198	6401.0	68.6
B4	23.411	6501.6	56.3
B5	23.558	6524.0	94.6
B6	23.580	6450.0	100.6
B7	23.376	6141.4	92.8
B8	23.575	6402.0	4.9
B9	23.532	6214.8	26.5
B10	24.114	6379.0	18.9
Average	23.517	6372.4	53.2

3.3 Tensile Strength

The Brazilian test, employed as an indirect method for measuring rock tensile strength, involves loading disk-shaped samples until failure. In Table 3, granite exhibited a range of tensile strengths, with the highest and lowest values recorded at 5.19 MPa and 2.93 MPa, respectively, resulting in an average value of 4.03 MPa. In contrast, basalt demonstrated a higher tensile strength range, reaching up to 14.59 MPa and having a minimum strength of 7.61 MPa, with an average of 10.09 MPa. These data highlight that basalt can withstand greater tensile strength compared to granite, aligning with the common observation that the tensile strength of rocks is generally much lower than their compressive strength, typically around 5 to 10% of the UCS value.

Table 3 *Tensile strength of granite and basalt*

Name of Samples	Density (kN/m^3)	Average Velocity (m/s)	Tensile Strength (MPa)
G11	26.04	5870.0	5.19
G12	25.96	5655.2	4.08
G13	25.92	5745.2	2.93
G14	26.98	5130.0	4.09
G15	26.12	5330.8	3.80
Average	26.01	4657.2	4.03
B11	26.73	6319.6	10.23
B12	26.90	6391.0	7.61
B13	26.94	6401.0	8.78
B14	27.22	6501.6	9.23
B15	31.68	6379.0	14.59
Average	27.09	5407.2	10.09

4. Conclusion

In summary, laboratory tests were conducted on two distinct rock types: granite and basalt. Basalt consistently yielded the highest values across all conducted tests—PUNDIT, UCS, and Brazilian. The results obtained in these tests remained within the lower range due to the chemical weathering process affecting both granite and basalt, causing the rocks to transition from a fresh to a non-fresh state and impacting their strength.

Acknowledgement

The authors would like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Hamizah Zainil;* ***data collection:*** *Hamizah Zainil;* ***analysis and interpretation of results:*** *Hamizah Zainil, Aziman Madun;* ***draft manuscript preparation:*** *Melvern Goh Keat Heng, Muhammad Aminuddin Khalid. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] M.H Zainal Abidin, A. Madun, M.F Tajul Baharuddin, BFC3013 Engineering Geology, Parit Raja, Johor: Penerbit UTHM, 2008, pp. 65-137.

[2] G. Mibei, "Introduction to types and classification of Rocks," in Short Course IX on Exploration for Geothermal Resources, Lake Bogoria and Lake Naivasha, Kenya, 2014.

[3] Oke, D. & Oladiran, G. & B., Raheem, "Correlation between Destructive Compressive Testing (DT) and Non Destructive Testing (NDT) for Concrete Strength," International Journal of Engineering Research and Science. 3, pp. 27-30, 2017.

[4] Z. A. Kamal, "Influences of water content and soil types toward p-wave velocity by using pundit test," Parit Raja, johor, 2015.

[5] N. Sivakugan, B. M. Das, J. Lovisa, C. R. Patra, "Determination of c and w of rocks from indirect tensile strength and uniaxial compression test," International Journal of Geotechnical Engineering, pp. 59-65, 2014.

[6] Servet D., Kenan T., Nazmi S., Tamer E., Rasit A., "Determination of the Direct Tensile Strength of Granite Rock by Using a New Dumbbell Shape and its Relationship with Brazilian Tensile Strength," in IOP Conference Series: Earth and Environmental Science, Turkey, 2019.

[7] Dai, F., Xia, K.W. & Tang, L., " Rate dependence of the flexural tensile strength of Laurentian granite.," International Journal of Rock Mechanics & Mining Sciences, p. 469–475, 2010.