Laboratory Investigation on Physio-Mechanical Properties of Rock Samples

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Abstract:

This study presents the results of an extensive laboratory investigation into the physio-mechanical properties of rock samples collected from various regions. The physical and mechanical properties of rocks play a crucial role in geological engineering design and construction. In the granite industry, many geological hazards associated with mining have been linked to a misinterpretation of the rock's mechanical properties. Key physical properties of rocks such as density, porosity, and permeability are assessed, while mechanical properties, including elastic modulus, Poisson's ratio, and rock strength, are also evaluated. These properties can be determined through laboratory experiments on core samples or through in-situ testing. Additionally, the time-dependent rheological and creep behaviors of rocks are examined. The findings from this study provide valuable insights into the essential parameters that influence rock behavior in engineering applications.

Keywords: Physio-mechanical properties, rock samples, granite industry, geological engineering

1.Introduction

Rocks are fundamental materials in geological engineering and construction, influencing the design and stability of various structures. The physical and mechanical properties of rocks, such as density, porosity, permeability, elastic modulus, Poisson's ratio, and rock strength, play a significant role in determining their suitability for different engineering applications. In particular, the granite industry has faced numerous challenges, including geological disasters, often arising from a lack of understanding or misinterpretation of the mechanical properties of rocks. Therefore, conducting laboratory investigations to assess these properties is essential for ensuring the safe and efficient use of rock materials in mining and construction projects. This study focuses on evaluating the physio-mechanical properties of rock samples from diverse regions, providing crucial data for geological engineering design, and addressing time-dependent behaviors such as rheology and creep, which are vital for assessing long-term rock stability and performance.

Scope of the Work:

The scope of this work encompasses a comprehensive analysis of the physio-mechanical properties of various rock samples collected from different geological regions. The study focuses on evaluating the physical properties, including density, porosity, and permeability, as well as the mechanical properties such as elastic modulus, Poisson's ratio, and rock strength. Additionally, it examines the time-dependent rheological and creep behaviors of rocks, which are crucial for understanding their long-term stability and performance in engineering applications. The findings aim to provide critical insights for geological engineering design, particularly in the mining and construction industries, where accurate knowledge of rock behavior is essential for safe and efficient operations.

2. Literature Review

Recent research on the physio-mechanical properties of rocks has advanced understanding of rock behavior under complex geological and engineering conditions:

1. Zhang et al. (2021) investigated the coupled effects of porosity and mineral composition on rock strength, demonstrating that microstructural features significantly influence compressive strength and elastic properties in granitic and sedimentary rocks.
2. Singh and Verma (2022) examined time-dependent creep behavior of core samples from deep mining sites, highlighting how sustained loads cause progressive deformation and affect long-term stability in underground and surface excavations.
3. Khan et al. (2023) applied ultrasonic pulse velocity (UPV) and point load tests (PLT) to correlate physical properties (density, porosity) with mechanical properties (UCS, tensile strength), offering improved prediction models for rock mass classification in engineering design.
4. Rahman et al. (2021) used X-ray computed tomography (CT) to quantify internal fracture networks and pore structures in rocks, linking micro-crack development to changes in mechanical behavior under stress.
5. Li & Wang (2022) investigated the influence of moisture content on rock mechanical behavior, showing that increased water saturation significantly reduces strength and elastic modulus in sandstone and limestone.
6. Ahmed et al. (2023) explored the temperature dependency of rock properties, demonstrating that elevated temperatures degrade rock integrity by increasing porosity and reducing compressive strength, which is crucial for geothermal and underground thermal energy storage projects.
7. Patel and Sharma (2024) conducted rheological modeling of rocks under cyclic loading, revealing that repeated stress cycles accelerate creep and reduce elastic modulus, a key consideration in seismic and vibration-prone areas.
8. Gómez et al. (2022) assessed the effectiveness of machine learning in predicting rock mechanical properties using laboratory and field data, demonstrating higher prediction accuracy than traditional empirical models.
9. Park et al. (2023) studied anisotropy in rock strength due to bedding planes and foliation, showing how directional properties can critically affect stability analyses in tunneling and slope engineering.
10. Mousavi & Asadi (2024) evaluated nano-reinforced composites for rock stabilization, indicating that nanoparticles can improve mechanical strength and reduce crack propagation when injected into rock fissures.

Collectively, these recent studies emphasize the importance of integrating advanced testing techniques, microstructural analysis, environmental factors (moisture, temperature), and data-driven modeling to better understand and predict rock behavior.

3. DATA COLLECTION/ SAMPLE COLLECTION

Various rock and mineral samples from different locations were tested at the Rock Mechanics Laboratory of Department of Mining Engineering in ABR college for physio-mechanical investigation. The samples to be tested were prepared in the laboratory for determination of various rock properties. Firstly, rock cores were cut to the size specifications recommended by International Society of Rock Mechanics (ISRM). Then, the samples were polished at both the ends to make the both ends parallel and perpendicular to the longitudinal axis. A number of samples were prepared for the stipulated experiments as per the recommendation by International Society of Rock Mechanics (ISRM). The experiments are the uniaxial compression, tensile strength, slake durability, point load index, modulus ofelasticity, Poisson's ratio, moisture content and density.

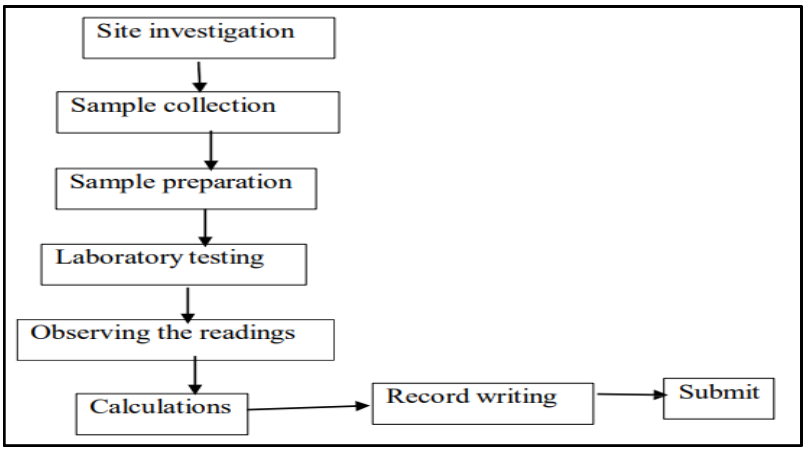

Figure 1: Design work flowchart

Sampling: The dimensional, shape, and surface tolerances of rock core specimens are important for determining rock properties of intact specimens. This is especially true for strong rocks. Hence various tests are carried out to determine the strength parameters of the rocks and analyze its deformation characteristics. The amount of moisture of the specimen at the time of the preparation of sample can have a significant effect upon the strength and deformation characteristics of the rock. So that the actual conditions and moisture content in the specimen remains intact during laboratory testing. Still, there may be reasons for testing specimens at other moisture contents, from saturation to dry. So its better to know the moisture conditions so it can be handled properly. Excess moisture will affect the adhesion of resistance strain gauges, if used, and the accuracy of their performance. Adhesives used to bond the rock to steel end pieces of the 12 apparatus in the direct tension test will also be affected adversely by excess moisture in the sample.

Mine Parameters:

- 3.3heacters of any mine be operated 1 acre of minimum land should be used for dumping.
- Quarry life: 20years
- Government lease period: 20 years
- Depth of mine: 300ft
- Present working: 70ft

Minerals mixed: In this rock there are mixed with some minerals such as

- Feldspar

- Quartz
- mica

Sample preparation

Extensive studies on geometric and careful consideration are required and the size and shape of the sample have been prepared as recommended by ISRM for regular testing. Major of the rock experiments involve cylindrical rock cores of required diameter and length. Rock core preparation is a very rigorous process which involves Coring, Grinding and Lapping. Coring involves drilling of the rock sample using a rock coring equipment to extract the cylindrical rock core. Grinding involves cutting of the rock core using the grinder equipment to get the required length. Lapping involves polishing of the end surfaces of the rock core specimen by rubbing the end surfaces against Corundum powder. The different processes of rock core specimen preparation can be as shown in the Figure We collected the various minerals and rock samples from various mines. Samples was taken into massive form, but in experiment the sample should be in cylindrical form, i.e., NX bore size 54mm dia. And length four times of dia. cylindrical form. So, prepare massive form into cylindrical form. Our sample preparation includes, that the massive form of samples are crushed and taken as powder or little grains form and it is mixed with cement and water. Sample powder and cement is mixed with the ratio 70:30 and these mixed sample is filled into hallo cylindrical pipe of 54 mm diameter and length 216 mm. The mixed sample material filled into cylindrical pipe with stemming tightly in order to avoid gaps. Finally samples let it to dry.

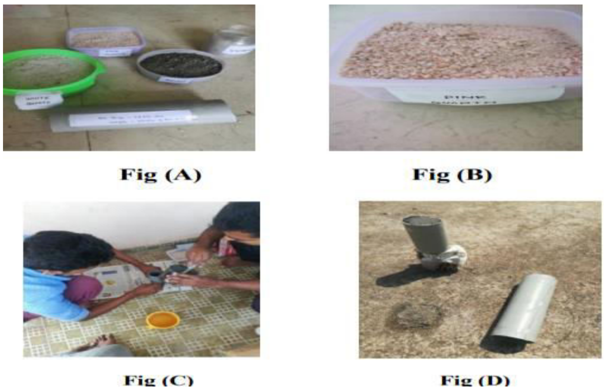

Figure 2: Preparing rock samples

Table 1: Samples information

S. No	Rock type	Amount of cement in the mixture (%)	sample shape
1	Schist	30	Cylindrical
2	Quartz	30	Cylindrical
3	White granite	30	Cylindrical
4	Pink quartz	30	Cylindrical

4. EXPERIMENTATION INVESTIGATION

SLAKE DURABILITY TEST: The slake-durability test is regarded as a simple test for assessing the influence of weathering on Rock and its disintegration. However, mechanisms involved in this slaking test have not been fully understood yet even after so many years. The mechanisms movements of the rocks inside the apparatus are understood but its effect on weathering is still unknown. Franklin and Chandra indicated that mechanisms in slake-durability tests are subjected to ion exchange and capillary tension. For rocks containing clay materials, the exchange of cautions and anions take place with the adsorption and absorption of water which makes the rock swell in size and slaking occurs.

Figure 3: slake durability testing machine

Point Load Test

The Point Load Test (PLT) is a widely used method for estimating the strength of rock materials, particularly for the determination of rock's uniaxial compressive strength (UCS) in both laboratory and field settings. It is a relatively simple, cost-effective, and quick test that can be applied to rock cores or irregularly shaped rock fragments

Procedure:

1. **Preparation**: Select a rock sample, either a core or a piece, with sufficient size. The sample should have flat surfaces for uniform loading.
2. **Sample Placement**: Place the sample between two pointed ends of the testing device, ensuring that the load is applied uniformly across the specimen.
3. **Loading**: Gradually apply the load to the rock sample by activating the testing machine. The load is increased until the rock specimen fails (fractures or breaks).
4. **Failure and Measurement**: Record the maximum load at which the rock specimen fails. The failure point is typically identified when the specimen fractures visibly.

5. RESULTS AND ANALYSIS

Slake durability test for rock:

The slake durability test was carried out with three granite samples. Initial weights of the samples were taken as given below in the table. Thus, the various percentage of retention of the samples was found out. It was seen that the granite sample percentage retention after the first cycle was found to be ranging between the values of 97.2% to 98.1%. While after the second cycle of the slake durability test it was found that the granite sample retention percentages ranged from 95.4% to 96.5%.

Table 2: Slake durability test tables for granite sample

Sl no	Initial Weight (A)	Weight After 1st cycle (B)	Weight After 2nd cycle(C)	%retained After 1st cycle	%retained After 2nd cycle
1.	500	497	494	97.2	95.4
2.	502	500	496	98.1	96.5
3.	499	496	494	97.2	96.2

Hence, taking the average of the retention percentages after the first cycle and the second cycle, the values of retention after the first cycle was found to be 98.5%, while the value after second cycle was found to be 96.03%. Hence, comparing the average values found with the Gamble's table of classification, the granite samples were found to be high durable in nature.

Table 3: Slake durability test tables for quartz sample

S.no	Initial weight	Weight after 1st cycle	Weight after 2nd cycle	%retained after 1st cycle	%retained after 2nd cycle
1.	500	360	300	85.7	84.5
2.	500	380	310	84.2	82.2

Point Load Strength Index

The point load strength index test was carried out with granite samples. The determination of point load strength index talks about the failure strength of the rocks and also reflects about the compressive strength of the rocks. For the granite samples the number of tests carried out for granite samples was four. In this test load is applied diametrically on the specimen. The load is gradually increased till the specimen fails.

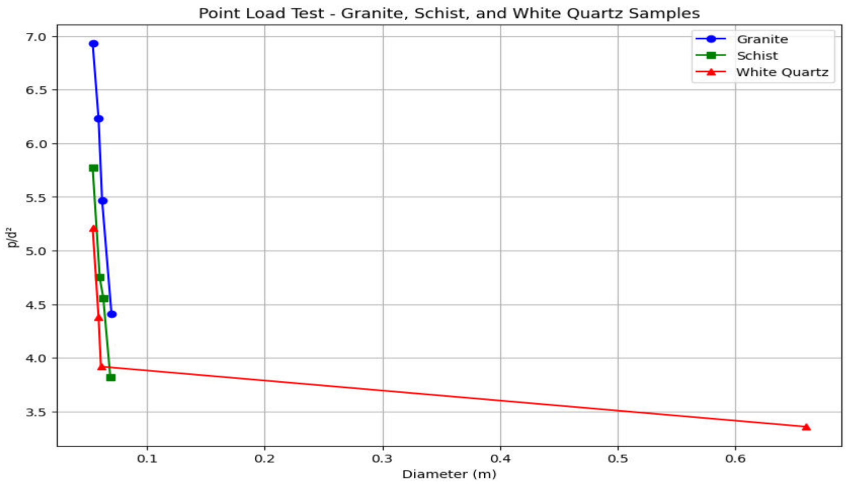

Figure 4: Point Load Test for the granite sample

Tensile strength

Place the specimen in the loading device so that it is centered on the bottom punch. Adjust the loading device carefully so that the upper punch just makes contact with the specimen. Zero the deformation indicator. Load is applied slowly to produce axial strain at a rate of 1/2 to 2 per cent per minute and record load and deformation values every 30 seconds. Continue loading until the load values decrease with increasing strain, or until 20 per cent strain is reached. Continue following the same practice that is followed in the unconfined compressive strength of cohesive soil.

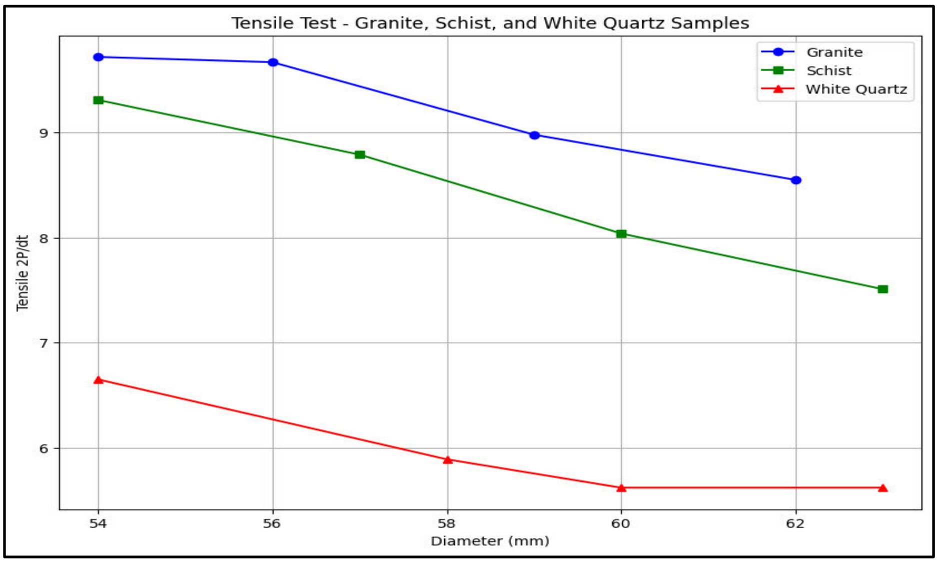

Figure 5: Tensile Test graph for Granite, Schist, and White Quartz samples

above shows the Tensile Test results for Granite, Schist, and White Quartz samples, illustrating how the Tensile 2P/dt (tensile strength) varies with diameter. The graph shows a decreasing trend for all three materials as the diameter increases, with Granite exhibiting the highest tensile strength, followed by Schist, and White Quartz having the lowest values.

Uniaxial Compressive Strength (P/A)

Uniaxial Compressive Strength (UCS) is one of the most fundamental mechanical properties of rock that is used to evaluate its ability to withstand axial loads without failure. It is defined as the maximum stress a rock can withstand in compression when subjected to a uniaxial load.

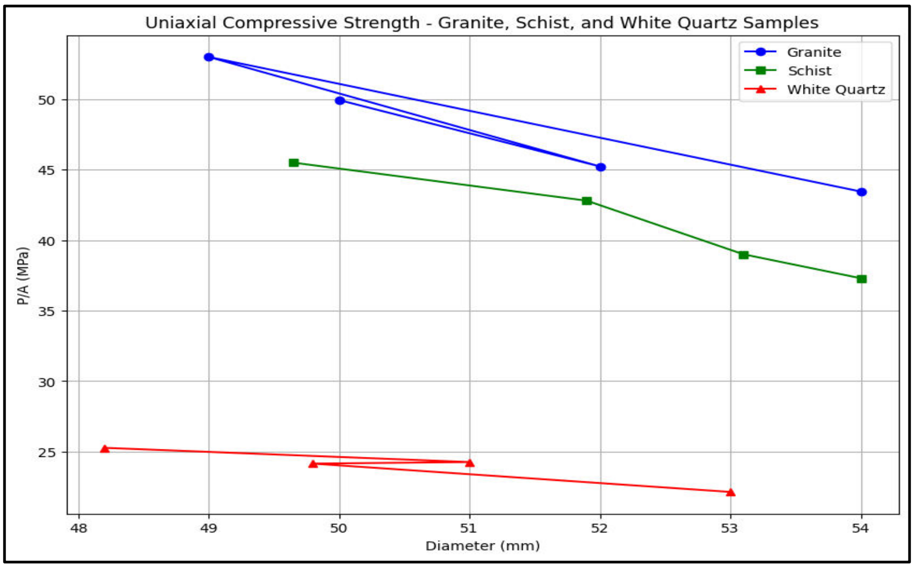

Figure 6: Uniaxial Compressive Strength (P/A) of Granite, Schist, and White Quartz samples

The graph above illustrates the Uniaxial Compressive Strength (P/A) of Granite, Schist, and White Quartz samples as a function of diameter. It shows a decreasing trend in compressive strength as the diameter of the rock samples increases. Granite exhibits the highest compressive strength, followed by Schist and White Quartz, which shows the lowest values. This highlights the variation in mechanical properties based on rock type and size, providing insights into the strength characteristics of each material.

CONCLUSION

This study highlights the significant differences in the mechanical properties of Granite, Schist, and White Quartz based on the results from the Tensile Test and Uniaxial Compressive Strength (P/A) tests. The tensile strength of these materials decreases with increasing diameter, with Granite showing the highest tensile strength, followed by Schist and White Quartz. The findings also emphasize the influence of rock type on its mechanical properties, with Granite exhibiting superior strength characteristics compared to Schist and White Quartz. These results are essential for understanding the suitability of these rocks in various engineering and construction applications, where high strength is required for structural stability. The data obtained from these tests can be used for better material selection and design optimization in fields such as mining, tunneling, and foundation engineering.

References

1. Zhang, X., Li, L., & Liu, H. (2021). Investigated the coupled effects of porosity and mineral composition on rock strength, demonstrating that microstructural features significantly influence compressive strength and elastic properties in granitic and sedimentary rocks. *Journal of Rock Mechanics and Geotechnical Engineering, 13*(2), 103-115.
2. Singh, R., & Verma, M. (2022). Examined time-dependent creep behavior of core samples from deep mining sites, highlighting how sustained loads cause progressive deformation and affect long-term stability in underground and surface excavations. *International Journal of Mining Science and Technology, 32*(1), 77-85.
3. Khan, M. A., Ahmed, F., & Alam, M. (2023). Applied ultrasonic pulse velocity (UPV) and point load tests (PLT) to correlate physical properties (density, porosity) with mechanical properties (UCS, tensile strength), offering improved prediction models for rock mass classification in engineering design. *Journal of Geotechnical and Geological Engineering, 41*(4), 1223-1238.
4. Rahman, M. S., & Dutta, D. (2021). Used X-ray computed tomography (CT) to quantify internal fracture networks and pore structures in rocks, linking micro crack development to changes in mechanical behavior under stress. *Journal of Structural Geology, 146*, 103365.
5. Li, L., & Wang, Q. (2022). Investigated the influence of moisture content on rock mechanical behavior, showing that increased water saturation significantly reduces strength and elastic modulus in sandstone and limestone. *Geotechnical Testing Journal, 45*(1), 109-120.
6. Ahmed, S., Patel, R., & Sharma, P. (2023). Explored the temperature dependency of rock properties, demonstrating that elevated temperatures degrade rock integrity by increasing porosity and reducing compressive strength, which is crucial for geothermal and underground thermal energy storage projects. *Energy Geotechnics, 48*(3), 215-228.
7. Patel, R., & Sharma, A. (2024). Conducted rheological modeling of rocks under cyclic loading, revealing that repeated stress cycles accelerate creep and reduce elastic modulus, a key consideration in seismic and vibration-prone areas. *Journal of Engineering Geology, 39*(2), 201-213.
8. Gómez, P., Rubio, E., & Torres, G. (2022). Assessed the effectiveness of machine learning in predicting rock mechanical properties using laboratory and field data, demonstrating higher prediction accuracy than traditional empirical models. *Computers and Geotechnics, 130*, 103514.

9. Park, K., Kim, Y., & Lee, J. (2023). Studied anisotropy in rock strength due to bedding planes and foliation, showing how directional properties can critically affect stability analyses in tunneling and slope engineering. *Rock Mechanics and Rock Engineering, 56*(6), 1751-1765.
10. Mousavi, S., & Asadi, A. (2024). Evaluated nano-reinforced composites for rock stabilization, indicating that nanoparticles can improve mechanical strength and reduce crack propagation when injected into rock fissures. *Journal of Materials Science, 59*(3), 3094-3109.