# ABSTRACT

## GEOTECHNICAL AND MINERALOGICAL ASSESSMENT OF GRANITIC ROCKS FROM NORTH WESTERN REGIONS OF PAKISTAN



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Granitoids hold significant importance due to their diverse properties and widespread applications across various industries. As durable and aesthetically pleasing materials, they are extensively used in the construction of buildings, monuments, and infrastructure projects. However, literature shows that certain factors affect the quality of granitic rocks, including mineral composition, texture, porosity, weathering resistance, the effect of temperature, scale effect including size and shape, and the presence of micro-cracks. Despite their suitability for construction, there remains a need for more detailed research. To address this, eight different textural varieties from northern Pakistan have been selected for investigation. These granitic rocks include Kesu granodiorite (KeG), Garam Cashma granite (GCG), Kumrat granodiorite (KG), Warai granodiorite (WG), Malakand granites (MG), Ambela granite (AG), Utla granite (UG), and Warsak Syenites (WS).

The mineralogy and the physico-mechanical properties, including specific gravity, water absorption, porosity, Uniaxial Compressive Strength (UCS), Uniaxial Tensile Strength (UTS), Schmidt Hammer Test (SHT), Ultrasonic Pulse Velocity (UPV), and Point Load Test (PLT), of these granitoids from North Pakistan were measured. Detailed aggregate tests were also conducted, covering Los Angeles Abrasion Value (LAAV), sulphate soundness, aggregate impact and crushing values, clay lumps, unit weight, flakiness, and elongation indices, and slake durability.

Three distinct strength classes are identified including high-strength properties (Grade-I) (KeG, WG, AG, GCG), intermediate-quality (Grade-II) (KG & WS) and low-quality (Grade-III) (MG & UG) granites. The strength properties of the studied granitic rocks in the region are significantly influenced by various factors, including their texture, quartz content, mineralogy, mineral alteration, the volume of void spaces, the presence of microfractures, and the size of mineral grains. The strength characteristics reveal a notable and statistically significant correlation between UCS and the grain size ($R^2$=0.84), quartz percentage ($R^2$=0.80), porosity ($R^2$=0.88), water absorption ($R^2$=0.95), specific gravity ($R^2$=0.69), PLT ($R^2$=0.98), UTS ($R^2$=0.98), SHT ($R^2$=0.92), and UPV ($R^2$=0.93) for the studied granitic rocks.

Thermal treatment (25°C to 1000°C) was found to decrease the strength of granitoids. Porosity and water absorption increased, while specific gravity, UPV, SHT, and both UCS and UTS exhibited a decline with rising temperature. The study identified a thermal damage threshold of 400°C, beyond which the microstructure and physical and mechanical characteristics of the rocks deteriorated, transitioning from brittle to ductile. The study observed significant mineral instability with increasing temperature, evident in thermally induced fractures and widening of pre-existing cracks. It is also noted that relatively altered rocks (MG and UG) are more susceptible to textural changes associated with heat treatment, observable at lower temperatures compared to other studied fresh granites (KeG, WG, AG, and GCG).

To determine the effect of shape and size of core specimens on rock strength, the study conducted comprehensive non-destructive testing using the SHT on forty bulk samples of granitic rocks, revealing R-values ranging from 29 to 55, categorizing them as slightly to very strong rocks with consistent values indicating sample homogeneity. Physical parameters such as specific gravity (2.63 to 2.82), dry density (2.87 to 2.61), water absorption (0.13 to 1.48), and porosity (0.28 to 3.83) fell within ASTM and ISRM ranges for construction materials. UPV values post-UCS testing correlated inversely with fracture counts, varying significantly between lower ($R < 2.0$) and higher ($R \geq 2.0$) R-values. UCS exhibited shape and size effects, with KeG showing the highest UCS values (up to 170 MPa), and UG displaying lower strength characteristics. Elastic modulus results showed no scale effect variation, consistent with previous studies. Application of literature-derived equations affirmed compliance with ISRM's recommended R-value ($\geq 2.5$) for shape effect and ASTM's diameter criterion (47-50 mm) for accurate UCS determination. Failure mode analysis identified shear and axial splitting as predominant failure modes during compression testing, highlighting critical failure mechanisms in granitic rocks.

This research also employs indices such as micro-petrographic index (Ip), Static rock durability index (RDIs), Dynamic rock durability indices (RDId), and slake durability index (SDI) on the investigated samples. Ip emerges as a reliable indicator for assessing the strength, durability, and weathering state of these rocks, providing insights into chemical weathering status, the presence of unsound minerals, and overall textural characteristics affecting durability and strength. Strong linear correlations between Ip and a range of physical and mechanical properties, demonstrating its comprehensive utility in evaluating rock properties. Overall, these findings highlight Ip's significance as a versatile tool for evaluating the durability and strength of igneous and metamorphic rocks across various geological and engineering contexts.