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ORIGINAL PAPER

Effects of grain geometry on the nondestructive testing results of hard rock materials

Sasan Ghorbani[1] · Seyed Hadi Hoseinie[2]

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Abstract
Investigating the effects of microfabric characteristics on the nondestructive parameters of rocks has always been one of the most challenging and hot topics in rock mechanics. This study focuses on how grain geometric characteristics affect Schmidt rebound hardness (SRH) and P-wave velocity (V_P). For this purpose, nine granites were selected for measuring the Schmidt rebound hardness and P-wave velocity. Next, eight grain geometric characteristics including roundness, roughness, aspect ratio, rectangularity, convexity, concavity, circularity, and solidity were quantified using the image processing method. Simple and multiple regression analyses were used to link these grain geometric features with SRH and V_P. The accuracy of the equations was checked using performance indices: coefficient of determination (R^2), Nash-Sutcliffe Efficiency (NSE), Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Scatter Index (SI). The simple regression analyses showed that circularity and aspect ratio have the greatest effect on SRH. Also, the circularity, roundness, and aspect ratio were found to be the most effective parameters on V_P. Finally, the results of multiple regression analysis demonstrated that there are highly significant relationships between SRH and V_P with the combination of grain shape characteristics, with R^2 of 0.999 and 0.988, respectively.

Keywords Grain geometric characteristics · P-wave velocity · Aspect ratio · Schmidt rebound hardness · Circularity

Introduction

In general, a single rock type can exhibit distinct microfabric characteristics, including mineral composition, size descriptors, geometric parameters, fabric coefficients, arrangement of mineral grains, and nature of grain-to-grain contacts (Diamantis et al. 2021; Askaripour et al. 2022; Ghorbani et al. 2022, 2023b; Ghorbani 2025). Previous studies have shown that the mechanical parameters of rocks are primarily controlled by their internal mesostructures, especially crystalline rocks (Wang and Yan 2023; Ghorbani and Bameri 2025). In other words, the engineering properties of rocks are related to microfabric characteristics. On the other hand, for measuring the physical and mechanical characteristics of rocks, direct destructive tests are expensive, time-consuming, and require a significant understanding of specimen preparation and high-tech equipment. These drawbacks have been addressed using inexpensive, fast, reliable, and indirect non-destructive testing (NDT) such as ultrasonic P-wave velocity and Schmidt hammer hardness (Ahmed et al. 2023). Therefore, assessing the effect of rock's microfabrical characteristics on non-destructive parameters is crucial.

In geology and rock mechanics, there are some well-established microfabric characteristics and indices. Meanwhile, grain geometric parameters like roundness, rectangularity, roughness, edge smoothness, circularity, irregularity, and angularity influence engineering properties in various rock types. The effect of microfabric traits on geomechanical properties has long been studied, revealing close relationships between these variables. A comprehensive literature review of links between grain geometry and geomechanical parameters is in Table 1.

Few studies have examined the relationship between grain geometric characteristics and nondestructive rock parameters. The effects of mineral grain geometry on

✉ Sasan Ghorbani
s.ghorbani@hut.ac.ir

1 Department of Mining Engineering, Hamedan University of Technology, Hamedan, Iran

2 Department of Mining Engineering, Isfahan University of Technology, Isfahan, Iran

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