Bulletin of Engineering Geology and the Environment (2026) 85:630
https://doi.org/10.1007/s10064-026-05274-7

ORIGINAL PAPER

Effects of thermal treatment and grain size on the basic friction angle of granite rocks

Soroush Imani[1,2] · Mahmoud Behnia[1,2] · Xuepeng Zhang[1,3] · Naser Golsanami[1,3]

Received: 6 November 2025 / Accepted: 16 August 2026

Abstract

This study explores how grain size, temperature, and moisture affect the shear resistance and microstructure of granitic rocks. The granite samples were categorized into three grain sizes: Fine (F), Medium (M), and Coarse (C). Specimens were prepared as 3 cm-thick slabs with overall dimensions of 7 × 7 cm to assess their basic friction angle. The experimental program examined the effects of temperature at 25 °C, 275 °C, and 525 °C, as well as a saturated condition at 25 °C, to evaluate variations in the basic friction angle from tilt tests. The changes in grain size across different temperatures were analyzed using thin section microscopy. Results show that the basic friction angle (φ_b) increases with temperature, with coarse-grained samples experiencing the most significant increase. Furthermore, φ_b rises with grain size across all temperature levels and this trend is well represented by a proposed linear regression model. Saturation also enhances friction, leading to the highest φ_b under room temperature saturated conditions. The comparison of the basic friction angle for similar and dissimilar surfaces revealed that the impact of temperature could be similar or different depending on the surface combinations. This research links grain size distribution to mineralogical composition and demonstrates a synergistic effect of temperature and grain size on the basic friction angle. This integrated approach builds on previous work by concurrently considering grain size, thermal and moisture conditions, and mineralogical factors in granitic materials.

Keywords Shear strength · Basic friction angle · Thermal treatment · Grain size · Saturation

Introduction

Rock masses consist of solid rock mixed with various discontinuities like faults, joints, and bedding planes. These features often play a more significant role in determining mechanical behavior than the rock matrix itself. This aspect is particularly important in civil and mining engineering, especially for surface rock masses that experience low confining pressures, where issues like block sliding or separation can lead to instability. That's why accurately assessing the shear strength of these discontinuities is crucial for evaluating structural stability and ensuring safe design (Rabat et al. 2022).Understanding rock slope stability is crucial for excavation projects in civil, mining, and geotechnical engineering. The challenges in accurately assessing this stability have sparked significant research into the peak shear strength of rough discontinuity surfaces, which play a key role in how failures occur. By determining the peak friction angle, we gain valuable insights into the frictional properties of these discontinuity planes and how well they can withstand shear stress (Serasa et al. 2017).

The shear strength of discontinuities can be evaluated through in situ and laboratory tests, including direct shear tests, or you can estimate it based on established shear strength criteria (Hencher & Richards 2015).Discontinuities found in nature usually have a rough appearance, with surfaces that are anything but smooth. In the 1970 s and 1980 s, drawing from earlier research, Barton and his colleagues put together empirical models to assess this roughness and its impact on shear strength (Barton & Bandis 1982).

✉ Naser Golsanami
golsanami_naser@yahoo.com

1 State Key Laboratory of Disaster Prevention and Ecology Protection in Open-Pit Coal Mines, Shandong University of Science and Technology, Qingdao 266590, China

2 Department of Mining Engineering, Isfahan University of Technology, Isfahan 8415683111, Iran

3 College of Energy and Mining Engineering, Shandong University of Science and Technology, Qingdao 266590, China

Published online: 04 September 2026