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Coupled mechanical–geophysical monitoring of rock fractures and damage

Hedayat, Ahmadreza, hedayata@ipfw.edu, Indiana-Purdue University Fort, Wayne

ABSTRACT

The study of rock fractures is essential in evaluating stability of underground structures, understanding earthquakes, and assessing storage and transport of oil and gas in rock formations. Geophysical monitoring techniques, particularly compressional and shear wave propagation, can probe the internal structure of rock and fractures remotely and nondestructively and can provide insight into fracturing processes. In this experimental study, geophysical monitoring and Digital Imaging Correlation (DIC) are coupled to evaluate the stiffness of rock fractures impending shear failure. An instrumented biaxial compression apparatus is used to conduct direct shear experiments on rock fractures in gypsum and Indiana limestone. During the tests, compressional, P, and shear, S, wave pulses are transmitted through and reflected off the fracture and the digital images of the specimen surface are acquired. To measure the stiffness of rock fractures, the displacement discontinuity theory, involving assumptions of discontinuous displacement but continuous stress across the fracture, is used and the dynamic fracture stiffness is determined based on the ratio of transmitted to reflected waveform amplitudes. In addition, the static fracture stiffness is calculated based on the fracture's shear displacement measured by DIC. A significant reduction in the fracture's local shear stiffness is observed well before failure occurs along the fracture. The dynamic fracture stiffness shows roughly five to ten times greater magnitude than the static values and this observation is linked to the fact that the dynamic strength moduli are typically greater than the static ones.