ABSTRACT

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The strength and deformation behavior of rocks are significantly influenced by the presence of discontinuities and fractures in the rock mass. Shearing along pre-existing discontinuities is the most common mode of failure in rock engineering and shear strength along discontinuities plays a major role in the stability of underground structures and rock slopes. One of the primary objectives of this research is to better understand the mechanical and geophysical processes that take place during shear failure of rock discontinuities. In this research active seismic monitoring, particularly compressional, P, and shear, S, wave propagation, was used to observe dynamic processes occurring in discontinuities impending shear failure. Seismic wave propagation and Digital Image Correlation (DIC) were employed to investigate slip processes along frictional discontinuities. Direct shear experiments were performed on gypsum, used as a rock-model material, and on Indiana Limestone specimens. Gypsum specimens were composed of two blocks with perfectly mated contact surfaces that were made by casting one block first and then the second against the first one, thus creating a well-mated contact surface. Non-homogeneous contact surfaces had low frictional strength on half the surface (smooth surface) and a high frictional strength on the other half (rough surface). In the experiments, the normal stress across the frictional surface was applied first and then the shear load was increased with a constant displacement rate until failure. Compressional and shear wave pulses were transmitted through and reflected off the discontinuity while digital images of the specimen surface were acquired during the test.

A distinct peak in the amplitude of transmitted waves and a marked decrease in the amplitude of reflected waves occurred prior to the peak shear strength of a discontinuity. These observations were identified as “seismic precursors” to the failure of the discontinuity. Seismic precursors were observed well before slip, or failure, occurred along the discontinuity. The sequence of

precursors observed while shearing indicated that along the non-homogeneous contact surface, slip initiated from the smooth surface and extended to the rough surface as the shear load was increased. From the DIC data, slip was identified as a jump in the displacement field across the discontinuity. The DIC showed that slip initiated from the smooth surface and propagated to the rough surface. Precursors were associated with an increase of the rate of relative displacement across the discontinuity (from DIC) and were a measure of a reduction of the fracture's shear stiffness (from wave propagation). The observed changes of amplitude of transmitted and reflected waves provided a mechanism for determining if slip along a discontinuity had occurred or was about to occur. This finding has numerous potential applications. First, it is a tool that can be used to assess the state of stress in discontinuities; it can also be used to detect discontinuities and damage inside materials; and it has the potential for having predictive capabilities for early warning of failures, e.g. earthquakes, and other instabilities due to shear failure.