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Kinematic Analyses of Rock Slope Failures Triggered by the Aysén 2007 Earthquake (Patagonia, Chile)

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Most studies related to earthquake triggering of rock slope failures are statistical investigations of the relationships between earthquake source properties to the spatial distribution of various landslide types, or strongly simplified dynamic stability analyses. Only very few investigators studied the detailed structural and kinematic properties of earthquake triggered rock slope failures. In this paper we present a detailed structural and kinematic analysis of ten rockslides with volumes ranging from 9[U+202F]000 to 1[U+202F]000[U+202F]000 m3 triggered by the Aysén Fjord Mw 6.2 earthquake of April 2007 (Southern Chile). Detailed structural data from the release areas in the steep and only rarely accessible terrain were generated from ground-based photogrammetry, combined with geodetic surveying using a rangefinder binocular connected to a GPS through a GIS-interface.

The orientations of discontinuities and release planes were measured in metric 3D images using the software ShapeMetriX3D. Kinematic analyses were applied using Markland methods with Hocking refinement to study possible failure mechanisms. Strength properties of fractures, rock and rock mass were assessed both from field work and laboratory tests on granodioritic and granitic samples. A detailed stability analysis of one selected rockslide was performed with simplified limit equilibrium methods and a two-dimensional numerical FE simulation using the code Phase2.

Based on the structural inventory from all release areas a regional structural analysis was performed, showing four evident systematic discontinuity sets (215/75, 275/55, 110/60, 155/65) occurring in the entire study area, and exerting a major control on the location of slope failures. A generic kinematic analysis leads to the conclusion that the distribution of earthquake-triggered rock slope failures of April 2007 is mainly controlled by the slope aspect and slope angle in relationship to these fracture set orientations, with preferential planar failure on east-, south- and west-facing slopes, wedge failure on south and west-exposed slopes and toppling mainly on north-facing slopes.

The kinematic analyses indicate no evident failure mechanism and no kinematic instability in 50% of the investigated cases which are mainly superficial rock slope failures with small volumes. The other 50% show kinematically unstable conditions and can be assigned to a planar and wedge failure mechanisms. In the latter cases we observed failed rock bridges in kinematically unstable release areas. The size of the rock bridges can vary between very small (cm) to large (m). Large rock bridges were observed in three rock slope failures, whereas small rock bridges have been difficult to detect in the study area because of size and limitation of access. The stress and failure analysis of the numerical simulation shows that the major stress at the rock bridges increases from 11 MPa to14 MPa during the earthquake, which succeeds the maximum shear strength received from laboratory testing (12 MPa). At the same time the maximum tensile strength is being succeeded at the rock bridges for the assumed seismic loading of the April 2007 Aysen earthquake.