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Granular Shear Zone Formation: Acoustic Emission Measurements and Fiber-bundle Models

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We couple the acoustic emissions method with conceptual models of granular material behavior for investigation of granular shear zone formation and to assess eminence of landslide hazard. When granular materials are mechanically loaded or sheared, they tend to produce discrete events of force network restructuring, and frictional interaction at grain contacts. Such abrupt perturbations within the granular lattice release part of the elastic energy stored in the strained material. Elastic waves generated by such events can be measured as acoustic emissions (AE) and may be used as surrogates for intermittent structural transitions associated with shear zone formation. To experimentally investigate the connection between granular shearing and acoustic signals we performed an array of strain-controlled shear-frame tests using glass beads. AE were measured with two different systems operating at two frequency ranges. High temporal resolution measurements of the shear stresses revealed the presence of small fluctuations typically associated with low-frequency ($< 20\,\mathrm{kHz}$) acoustic bursts. Shear stress jumps and linked acoustic signals give account of discrete events of grain network rearrangements and obey characteristic exponential frequency-size distributions. We found that statistical features of force jumps and AE events depend on mechanical boundary conditions and evolve during the straining process. Activity characteristics of high-frequency ($> 30\,\mathrm{kHz}$) AE events is linked to friction between grains. To interpret failure associated AE signals, we adapted a conceptual fiber-bundle model (FBM) that describes some of the salient statistical features of failure and associated energy production. Using FBMs for the abrupt mechanical response of the granular medium and an associated grain and force chain AE generation model provides us with a full description of the mechanical-acoustical granular shearing process. Highly resolved AE may serve as a diagnostic tool not only for detection of shear zone development and straining in granular matter and but also for investigating internal grain scale mechanical processes. The AE method could be integrated into monitoring networks of landslide-prone slopes and other early warning systems for abrupt mass release (snow avalanches).