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In-situ measurements of stress anisotropy in natural debris flows

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Stress anisotropy affects the motion of gravitational mass flows, including debris flows, rock and snow avalanches. Though widely used in analytical models and numerical simulation tools, direct measurements of stress anisotropy in debris flows are not yet available. The present study aims to investigate the ratio of longitudinal to normal pressure exerted by two natural debris flows impacting a monitoring structure in the Gadria creek, IT. The fin-shaped structure in the middle of the channel is equipped with a force plate upstream of the barrier and load cells on the vertical wall of the barrier, continuously recording forces in flow and bed-normal direction. Additionally, the flow height and basal pore fluid pressure were measured. Here we present data from surges of two debris-flow events with peak flow heights of 2.5 m and velocities up to 4 m/s. The ratio of pore fluid pressure to normal stress (often termed liquefaction ratio) reached values up to 0.8. We find an anisotropic stress state during most of the flow event, with stress ratios ranging between 0.1 and 3.5. Video recordings reveal complex deposition and re-mobilization patterns in front of the barrier during surges and highlight the unsteady nature of debris flows. We find a correlation of the stress ratio with flow depth. There is a weak correlation between stress ratio and liquefaction ratio during the falling limb of the surge hydrographs. Our monitoring data confirm the assumption of stress anisotropy in natural debris flows and support the earth-pressure concept used for gravitational mass flows.