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Shear weakening with increasing temperature: effect of clay fraction in low plasticity soils from the Melamchi catchment in Nepal

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The shear strength is a fundamental mechanical parameter that controls the occurrence and propagation of landslides. In pure clays, this parameter is temperature-dependent according to the clay's mineral composition and hydro-mechanical boundary conditions. Landslide soils are typically heterogeneous mixtures with a variable content of clay minerals. Particularly for low-plasticity soils, the impact of changes in temperature on the mechanical response remains to be determined, and little can be said about possible macroscopic alterations of slope stability or landslide dynamics.

In this study, we conducted ring-shear tests using natural soils from the Melamchi catchment in central Nepal, which suffered widespread instabilities and rainfall-induced debris flows. We performed experiments under typical landslide stress levels (50-150 kPa) in water-saturated conditions and under a constant rate of shearing (0.1 mm/min). We controlled the temperature during testing and performed a heating-cooling cycle (20-50-20 °C) only after attaining the residual shear condition. We prepared multiple samples from the same soil by retaining its finest portion under different cutoff grain sizes (0.125-0.020 mm) to evaluate the fine fraction's role in the thermo-shear response.

As expected, we observed a decrease in shear strength with the clay fraction increasing. Samples with a coarser cutoff (and hence a lower clay fraction) did not exhibit any change in shear strength during the heating-cooling cycle. However, as the clay fraction increased, a heating-induced weakening emerged, corresponding to up to a 1° difference in friction angle in the samples with a 0.020 mm cutoff. In the specific case study, this weakening may be minor and will not affect evaluations of slope stability in simple limit equilibrium analyses, especially in the absence of explicitly accounting for spatial heterogeneities in soil properties and boundary conditions. Nevertheless, incorporating this effect into physically-based models, either entailing advanced soil constitutive models or equations for surface flows (both of which can include additional temperature-dependent parameters), may provide useful insights into the complexity of thermo-hydro-mechanical responses and their effects on landslides at the local and regional scales.