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Temperature-dependent residual shear strength characteristics of smectite-rich landslide soils

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On gentle clayey slopes in weathered argillaceous rock areas, there exist many landslides which repeatedly reactivate with slow movement. The slip surface soils of these landslides are sometimes composed dominantly of swelling clay mineral (smectite) which is well known to show extremely low residual friction angle. From field data monitored at landslide sites in Japan, it has become clear that some landslides with relatively shallow slip surface begin to move and become active in late autumn or early winter every year. In such cases, the triggering mechanisms of landslides have not been understood well enough, because landslide initiation and movement are not always clearly linked with rises in pore water pressures (ground water levels).

In this study, we focus on the influence of seasonal variation in ground temperature on slope stability and have investigated the effect of temperature on the shear strength of slip surface soils. Undisturbed soil samples were collected by boring from the Busuno landslide in Japan. We performed box shear experiments on undisturbed slip surface soils at low temperature ranges (approximately 5-25 ℃). XRD analysis revealed that these soils contain high fraction of smectite. Slickensided slip surface within test specimen was coincided with the shearing plane of the shear box and shear displacement was applied precisely along the localized slip surface. Experiments were performed under slow shearing rate condition (0.005mm/min) and the results showed that shear strength decreased with decreasing temperature. Temperature effect was rather significant on frictional angle than on cohesion.

Ring shear experiments were also performed on normally-consolidated remoulded samples. Under residual strength condition, temperature-change experiments (cooling-event tests) ranging approximately from 5 to 25 ℃ were performed on smectite-rich landslide soils and commercial bentonites. As well as the results by box shear test, shear weakening behaviors were also recognized during cooling-event tests. Shear stress fluctuations, which were obtained by 1 Hz data sampling, showed that shear behavior characteristically changed in response to temperature conditions. Stick-slip behavior prevailed under room temperature conditions, whereas shear behavior gradually changed into stable sliding behavior as temperature decreased. SEM (Scanning Electric Microscope) observation on shear surfaces indicated that silt- and sand-size asperities in the vicinity of the shear surface influence the occurrence of stick-slip behavior. It is also characteristically noted that rod-shaped smectitic clays, here called “roll”, developed on shear surfaces and are arrayed densely perpendicular to the shearing direction in a micrometer scale. We assume that these rolls are probably rotating slowly within shear zone and acting as a lubricant which affects the temperature-dependent frictional properties of the shearing plane.

These experimental results show that residual strength characteristics of smectite-rich soils are sensitive to temperature conditions. Our findings imply that if slip surface soils contain a high fraction of smectite, a decrease in ground temperature can lead to lowered shear resistance of the slip surface and triggering of slow landslide movement.