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Effect of temperature on shear strength of slip surface clay taken from a slow-moving landslide activated in cold season

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Landslides in Japan are often associated with occurrence of swelling clay minerals such as smectite that are frequently found in Tertiary deposit rocks or layers altered by hydrothermal processes in volcanic region. Because residual friction angle of smectite is very low, landslides with slip surfaces that are rich in smectite can become easily unstable in very gentle slopes. Such landslides tend to move very slowly for a long time. Velocity of such landslides are approximately 0.01-0.1mm/min statistically. In addition, those which became active during winter revealed various behavioral patterns when monitored. Their activities start from late autumn to snow-melting season. Some landslides stop moving during heavy snow period. It is not fully understood what kinds of factors control such various behaviors. Shallow and small-size landslides generally start moving from early winter (late autumn to early snowy season) which led us to suspect seasonal fluctuation of underground temperature affecting the slope stability. In the recent years, the authors have conducted experiments focusing on the temperature dependency of shear strength of soils, and revealed that residual strength of soils rich in smectite is strongly affected by temperature condition (Shibasaki and Yamasaki, 2010). In this paper, we carried out an additional experiment in order to investigate the mechanism of slow-moving landslides activated in winter.

We directly tested the effect of temperature on shear strength of slip surface, using an undisturbed sample taken from a landslide in Joetsu district, Niigata prefecture found in Neogene sedimentary rocks. X-ray diffractometer analysis of slip surface clay showed that dominant clay mineral is smectite. Direct shear test was performed on the drilled core sample containing slickensided slip surface at the depth of GL-4.5m. A test was carried out under normal stress of 50kN/m2 to reproduce the effective normal stress in the field. Shear rate of 0.005mm/min was applied. Temperature of the specimen was controlled by a shear box bath filled with water which circulated from temperature-controlled bath installed outside which changed from 14 to 27 degrees centigrade during the test. When temperature dropped, shear strength coincidentally decreased. This result matches with ring shear experiments performed on reconstituted samples of smectite-rich clayey soils (Shibasaki and Yamasaki, 2010). Furthermore, the results support the hypothesis that seasonal fluctuation of underground temperature lower shear strength of slip surface and can trigger landslide movement.

Keywords: slow-moving landslide, swelling clay mineral, smectite, residual strength, temperature dependency, cold season