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Estimation of landslide deformation process based on comparison of inclination rate and displacement rate

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At the Shionokawa Landslide, the Research Association for Development of Observation Devices used in Special Landslide Environments installed the IT Ground Tiltmeter System developed through joint research (PWRI et. al. 2009) at 6 locations from behind the main landslide scarp of the landslide to its bottom, and used them to perform observations at 1 hour intervals. Both the backward rotation and forward rotation had been confirmed by instruments, and the largest tilt was recorded by IT-4, where the slide rotated backwards towards the landslide scarp side at a speed of 0.87degree per year. A method to utilize the observation data of the ground inclination at the landslide site has been studied. The landslide mass deformation process from the time of occurrence until now was consistently estimated by combining the inclination and the displacement vectors obtained by the the moving stake observations (Uto et al., 2011). Translation sliding and rotation sliding combined to leave the internal structure unchanged without conspicuous abrupt displacement, as gradual deformation occurred. But some problems have been clarified. For example, (1) analysis including the behavior at the time of an earthquake is necessary to estimate the deformation process of a landslide at a longer time scale, and (2) verification is necessary based on the comparison of landslide cases where the rotary motion is predominant.

In our research, (1) we analyzed the deformation of the Shionokawa Landslide, that occurred following the Great East Japan Earthquake, and (2) analyzed the data of the Toi Landslide together with the Shionokawa Landslide data and proposed a widely applicable utilization method.

For the behavior of the Shionokawa Landslide before and after the outbreak of the Earthquake, although clear tilting was observed during the earthquake, the amount of inclination was only greater by about one-year's increment than the rate in the ordinary time, and the inclination rate decreased in either of them after the earthquake. The moving stake observation results also indicate the similar tendency (below figure), suggesting the possibility that the Shionokawa Landslide temporarily lulled rather than accelerated by the earthquake.

In addition to the Shionokawa Landslide, we focused on the Toi Landslide, which is an about 40 m wide colluvial landslide with an inclination rate a digit greater than the former and conducted comparison and analysis of the inclination rate measured with IT ground tiltmeter (PWRI et al. 2009) and the displacement rate measured with extensometers installed on the landslide scarp to make comprehensive evaluation. It then allowed us to arrive at the correlation of $y=kx$ for the inclination rate, x (rad/day), by the backward rotary motion measured with ground tiltmeters installed in the landslide and the displacement rate, y (m/day), obtained from ground extensometers or moving stakes placed at the landslide head. Assuming these correlation are produced by the rotary motion of the radius, r_2'(m), on the ground surface, it then leads to $r_2'=k$=14.2 - 18.0 for the Toi Landslide and $r_2'=k$=35.4 - 42.2 for the Shionokawa Landslide. On the other hand, the rotary motion of the radius, r_2(m), estimated based on the estimation from the landslide geometry, r_2 = about 16 and r_2=36 respectively, leading to almost the same results with r_2'. For a landslide with rotary motion predominantly observed, it is suggested that the comparison and analysis of the displacement rate and inclination rate contributes to clarification of the deformation mechanism of the landslide. Further improvement in precision of estimation of the deformation process of a landslide that has an arc-shaped slip surface or of the shape of the slip surface is expected by those analyses and the method to estimate slip surfaces obtained from moving stake observation (Ishida et al, 2011).

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Keywords: landslide, IT Ground Tiltmeter System, rotational slide, displacement vector, deformation process, Great East Japan Earthquake

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