論文の内容の要旨

Title of Thesis: ***Prediction for shallow landslides based on time history of tilting of slope surface***

（斜面表層の傾斜の経時変化に基づく浅層すべりの予測）

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Landslide disasters, which are mainly caused by heavy rainfalls and strong earthquakes, are the major threat to human lives and infrastructures. Every year thousands of fatalities and billions in property are damaged by landslide disasters. The huge economic losses and casualties associated with landslide disasters led to research on prevention and mitigation of landslides. Nowadays, retaining walls and ground anchors which improve the factor of safety against failure, have been widely used as typical methods to prevent slope failures. However, these methods are highly cost, and not suitable for a large number of slopes with potential risk of failure. Currently, landslide early warning systems using inclinometers, tilt sensors, extensimeters, or other monitoring equipements, have been developed and considered as promising methods to reduce the risk of damage in human as well as properties caused by landslides. In these systems, the tilting of slope surface monitoring systems using tilt sensors with lower-cost and easier installation, are widely used in landslide monitoring. However, the method for landslide occurrence prediction based on tilting behavior of slope surface is still under consideration.

Nowadays, the most of landslide predicting methods are based on the relationship between the rate of displacement and duration time before failure, which was approached from the creep tests and model tests under constant rainfall intensity. In recent decades, from the existing monitoring data of slope surface measured by extensometers and tilt sensors respectively, a similar trend has been observed between

surface displacement and tilting angle against time after the onset of slope sliding, but there is limited research have been done to explore this trend. This study attempts to investigate the relationship between the surface displacement and tilting angle, and then develop a new method for landslide occurrence prediction based on time history of tilting of slope surface. Laboratory model tests, with pre-defined slipe surfaces as well as with different testing materials, were conducted under different triggering factors for slope failure and using tilt sensors attached to various lengths of rods. In small-scaled model tests, the slope failure was induced by tilting the container or applying the artificial rainfall. In the tests, the displacement and the tilting angle of the slope were measured. Additionally, field tests were also carried out. In field tests, the extensometers were used for the displacement monitoring and the tilting sensors with different length of steel rods were employed for measuring the tilting angle of slopes. The test results from the model tests and the field tests show that tilt sensors with no rods or short rods located above the slip surface will tilt backward while the tilt sensors will tilt forward if the rods of tilt sensors reaching the slip surface. Furthermore, a linear relationship between the displacement and tilting angle of slopes was found from the results in model tests as well as in field tests. By substituting the relationship between the displacement and tilting angle of slopes into the existing landslide prediction method based on the rate of displacement, a new method for landslide occurrence prediction is proposed utilizing the time history of tilting of slope. This new proposed method was validated by model tests as well as field tests. This method was also used for a real-time slope monitoring, and the result shows that this method has practical importance.

Keywords: Landslide monitoring; relationship; displacement; tilting; prediction.