Characteristics and prediction of rainfall induced shallow landslide in Kangwon Prefecture of Korea

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1. Introduction

Rainfall-induced shallow landslides have been studied for practical and scientific reasons (Iverson et al., 2000). In spite of their size, shallow landslides pose a significant hazard to mountain communities because they are frequent, difficult to predict, and they can develop into debris flow, which are potentially destructive due to their velocity and their bulking capability during propagation (Campbell, 1975; Iverson et al., 2000). Several shallow landslide models have been developed on the basis of the infinite slope equation. Both models, however, have shortage to predict shallow landslide related to rainfall intensity factor that occurring shallow landslide. In this study, the soil depth data and real soil data collected from study area of Korea were used to predict critical rainfall by using H-SLIDER made by PWRI(Public Works Research Institute in Japan).

2. Description of shallow landslide model (H-slide by PWRI)

The mathematical models, SINMAP(Pack et al., 1999) and SHALSTAB (Montgomery and Dietrich, 1994), developed by Montgomery and Dietrich (1994), Pack et al. (1998) available for studying shallow landslides, take into account the infinite plane slope stability model coupled with a steady state topographic hydrologic model. Both models use the same equation for factor of safety and Darcy's law for saturated flow within the soil to estimate the spatial distribution of pore pressures. The factor of safety calculation (FS) is based on the infinite slope form of the Mohr–Coulomb failure law as expressed by the ratio of stabilizing forces (shear strength) to destabilizing forces (shear stress) on a failure plane parallel to the ground surface(Hammond et al., 1992).

$$FS = \frac{c + [\gamma h \cos^2\theta - u(t)]\tan\phi}{\gamma h \cos\theta \cdot \sin\theta} \quad (1)$$

where c = cohesion [N/m^2], γ =unit weight of soil layer [N/m^2], θ =slope angle, h =soil depth [m], u =pore water pressure [N/m^2] and ϕ is the internal friction angle [°].

In here, when FS assumed 1, the failure is occurred and the equation (steady state critical rainfall mm/h) by Uchida (2009) can be developed.

$$r_c = \frac{K_s \tan\theta \cdot \cos\theta\{c - r_t h \cos\theta(\sin\theta - \cos\theta\tan\phi)\}}{A\{r_w \cos\theta\tan\phi + (r_s + r_t)(\sin\theta - \cos\theta\tan\phi)\}} \quad (2)$$

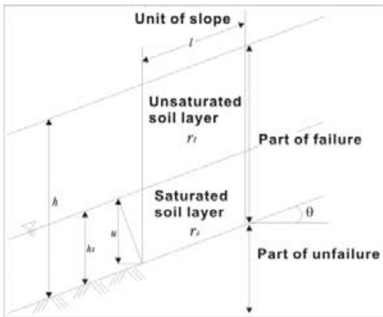

Fig.1. Schematic illustration of cross section of the model (Uchida, 2009)

where r_c is a steady state critical rainfall K_s is saturated hydraulic conductivity, r_w is an unit weight of water

3. Survey of study area in Korea

Study area, located on northern part of Korea, is characterized by very weathered granite. This area is one of areas developed from many shallow landslides in 2006, due to high intensity rainfalls that mobilized some dormant slides. The dynamic cone penetrometer (25-mm diameter with 60° tip angle), known also as the knocking pole was used (Onda, 1996). Nc is defined as the number of impacts needed for every 10-cm penetration using Nc-values by Uchida et al. (2009). Accordingly, the thickness of soil mantle is defined as the depth attained when the Nc reaches 30. And soil samples were collected within 1 m of the failure scars of two debris flow failures and two slumps. The testing of soils to understand their behavior during shallow failures requires a method that mimics the stress field under natural conditions. Shallow landslides are triggered by elevated pore pressures that decrease the effective normal stress (i.e., the normal load minus the pore pressure) rather than by an increase in the shear stress Whereas typical tri-axial shear testing is done by increasing the shear stress, the CD test approximates the conditions during rainfall-induced failure by holding the shear stress constant while reducing the effective stress.

4. Results and discussion

4.1 Soil depth and soil properties

The soil depth ranges were 0 ~ 230cm and were average 1.04m in study area using by knocking pole test (Fig. 2). Collected soil samples were analyzed using a tri-axial compress experiment (CD test) to obtain soil properties (table 1) and to make input data to H-SLIDE.

Table 1 Properties of soil samples

AREA OF STUDY	Sample 1	Sample 2
Hydraulic conductivity	0.000358 m/s	0.000195 m/s
Internal Friction Angle	33.3	36.5
Soil cohesion	2	0.1
Unit weight of saturated soil layer	15.47	15.36
Unit weight of unsaturated soil layer	15.1	14.92
Unit weight of water	9.8	9.8

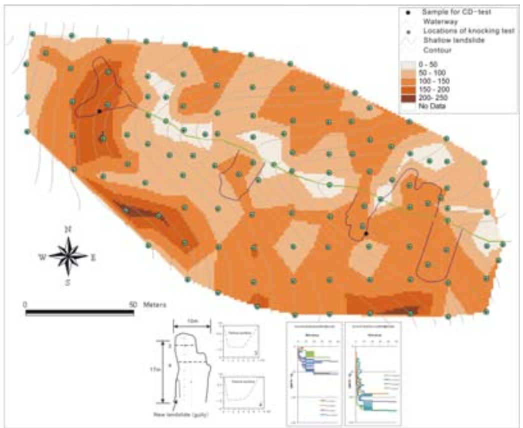

Fig. 2 Survey of study area and analysis of soil depth using a knocking pole test

Although the samples have been taken in same study area, factors of soil had different properties (table 1). This means that the properties of soil are one of the important factor to perform a simulation

4.2 Analysis of critical rainfall

The distribution of critical rainfall intensity (r_c) in the study area is shown in Fig. 3 and, the hydraulic conductivity and soil depth were very sensitive in this study.

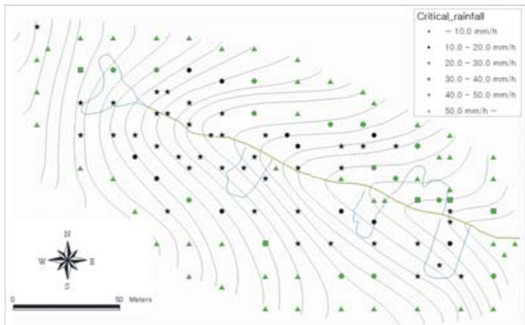

Fig.3. Spatial variability of calculated critical steady state rainfall intensity (measured soil depth).

The most common slope instabilities in soil layer are an initial shallow rotational or translational slide followed by flowage of the disturbed mass, which occur following periods of heavy rainfall. The infiltration of rain (saturation from above) and/or rise of a temporarily water table, in contact with the less permeable bedrock, increase the pore pressure and cause a reduction in shear strength of the soil material. Consequently, landslides are found related to the rainfall intensity and rainfall duration.

5. Conclusion

The critical rainfall intensity (mm/h) that occurring shallow landslide was calculated using a H-SLIDER in this study. Many landslide models like shalstab and sinmap have been developed and used it due to convenience. These models; however; have shortages for analyzing landslides because they are difficult to predict critical rainfall data that occurring shallow landslide. And hydraulic conductivity was also important to accuracy modeling in this study.

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