A FINITE ELEMENT APPROACH TO UNDERSTAND THE CREEPING BEHAVIOR OF LARGE-SCALE LANDSLIDES

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1. INTRODUCTION

Most large-scale landslides exhibit creep displacement behavior and the movement rate of these landslides vary zero to few centimeters per year. Many-large scale landslide sites accommodate human settlement, agricultural fields, alignment of various roads and highways, bridges and tunnel, and conservation of land and nature sites etc. When the displacement rate of such landslides is suddenly increased, a huge mass of soil is failed, causing a huge damage and loss of life, infrastructure, nature, and so on. This necessitates the importance of further studying creeping displacement behavior of large-scale landslides. In previous study, most of the theoretical models and numerical models are not well addressed the time-dependent behavior of soils and not sufficient to predict the creeping behavior of landslide soils. Moreover, slow-moving or creeping type landslides are controlled by the groundwater fluctuations (Conte et al., 2014, Ishii et al., 2012), therefore groundwater fluctuations should be considered during the study of the creeping behavior of such landslides. In this study, a finite element approach is proposed to evaluate the creeping behavior of a large-scale landslide considering the ground water fluctuations within the slope. An elasto-viscoplastic constitutive model is used in this approach to simulate the creeping behavior of clayey soil in the shear zone. The proposed model is also applied to understand the creeping behavior of Tomuro landslide of Gunma Prefecture, Japan to check the applicability of the proposed model. It is believed that the proposed numerical approach will be applicable for the better understanding of creeping behavior of large-scale landslides and their failure mechanisms. Moreover, this study may be useful for a long-term landslide management system in future.

2. FEM MODEL

Based on the literature reviews, Sugawara (2003) has reported that the displacement rate is inversely proportional to the factor of safety for creeping type of landslides. Based on that concept, we have established a relationship between displacement rate and factor of safety considering the field monitoring data of groundwater fluctuations and displacement, as shown below [Eq. (1)].

$$\dot{\gamma}_{max} \leq \frac{\dot{\propto}}{{F_{s,local}}^{n}} \tag{1}$$

Where, $\dot{\gamma}_{max} =$ displacement rate, $F_{s,local} =$ local factor of safety, and, $\dot{\propto}, n =$ constitutive parameters.

The Eq. (1) is incorporated in the traditional 2D elasto-viscoplastic constitutive model for the better understanding of the creeping behavior of large-scale landslides. In previous 2D elasto-viscoplastic constitutive model (Conte et al., 2014, Ishii et al., 2012), one parameter was considered, however, this model has incorporated two control constitutive parameters for performing realistic problem of the large-scale landslides.

3. APPLICATION OF FEM MODEL

The proposed model is applied to analysis the creeping behavior of Tomuro landslide of Gunma, Japan. Fig. 1 shows the 2D finite element mesh used for the analysis, which is prepared based on the geological x-section of the slope of such landslide site. The major three materials (layers) were observed from the boreholes details of such landslide. The weakest material (i.e., indicating by red color in Fig. 1) is named as “Sliding surface”. The thickness of this layer is about 1m. The strongest material (i.e., green color) consists at the bottom of model, referred as “Pumice tuff”. The reaming material (i.e., yellow color) is stronger than Sliding surface but weaker than Pumice tuff, is referred as “Weathered rock”. The mesh adopted in the calculations consists of rectangular element with eight nodes. The base of the model is assumed to be fully impervious and fixed, and the lateral side (right) is constrained by rollers. The hydraulic head is imposed at the lateral boundaries based on the field monitoring results of groundwater level (Fig. 1).

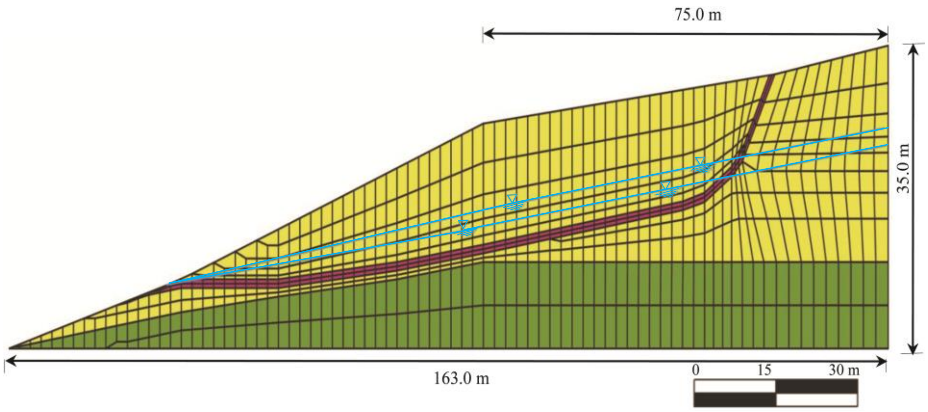

Fig. 1 Finite element model of Tomuro landslide

Keywords: Finite Element Method, Large-scale landslides, Ground water fluctuations, Creeping behavior
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Table 1 Materials parameters for landslide simulation

Parameters (↓) \ Materials (→)	Weathered Rock	Sliding Surface	Pumice Tuff
Young's modulus, E (kN/m^2)	3000	1000	50000
Poisson's ratio, ν	0.40	0.30	0.45
Cohesion, c′ (kN/m^2)	50	10.27	5000
Internal friction angle, ϕ′ (deg.)	30	20.90	30
Dilatancy angle, ψ (deg.)	0	0	0
$\dot{\alpha}$ (¯s)	6.37	6.37	6.37
n	56	56	56
Unit weight, γ (kN/m^3)	20.0	18.0	25.0

Table 1 tabulates the materials parameters for landslide simulation. The young's modulus of Sliding surface was obtained from the Uniaxial Compression (UC) test. Similarly, the cohesion and internal friction angle were estimated by using Triaxial tests results of undisturbed block samples. From 2014/1/14 to 2015/7/6, systematic measurements of groundwater level and displacement of the landslide body were performed every day. Such results were used to establish the relation between the displacement rate and local factor of safety. The unknown constitutive parameters ($\dot{\alpha}, n$) were estimated based on the well fitted curve between the displacement rate and local factor of safety (i.e, $\dot{\gamma}_{max}$ Vs $F_{s,local}$).

The results of the model are presented in Fig. 2 and Fig. 3. The red dot line shows the result of deformation pattern (Fig. 2). Similarly, the result of shear strain pattern is presented in Fig. 3. It is clearly shows that maximum shear strain and maximum deformation were occurred in the sliding surface. This means that the proposed model results are in good agreements with the field monitoring and analysis results of Tomuro landslide. Therefore, the proposed FEM model can apply to study the creeping behavior and failure mechanisms of large-scale landslide problems in future.

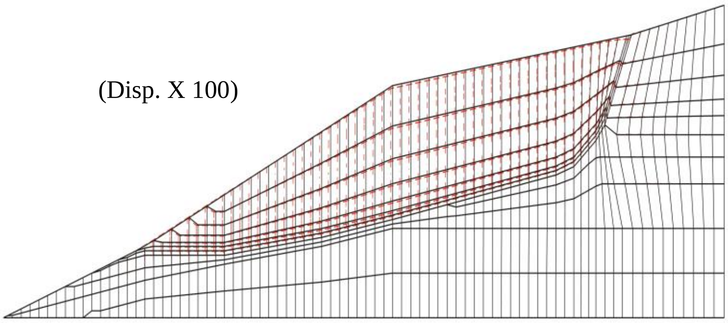

Fig. 2 Results of deformation pattern

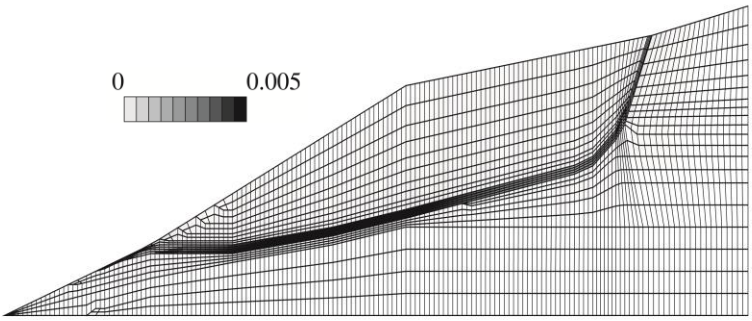

Fig. 3 Results of shear strain pattern

4. CONCLUDING REMARKS

A finite element approach has been proposed to evaluate the creeping behavior of large-scale landslides owing to ground fluctuations. In this elasto-viscoplastic constitutive model, two control parameters ($\dot{\alpha}, n$) were incorporated for the first time to understand the creeping behavior of large-scale landslides. The proposed numerical approach is applied to analysis the creeping behavior of soil in the shear zone of Tomuro landslide of Gunma, Japan. It is believed that the proposed numerical method will be applicable to understand the creeping behavior of any large-scale landslides and also useful for preventive counter measure works to control the mobility of such landslides in future.

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