MECHANISM OF LANDSLIDE BEHAVIOR AT AN UNSTABLE SLOPE CAUSED BY CHANGES OF THE GROUND WATER LEVEL

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1. INTRODUCTION

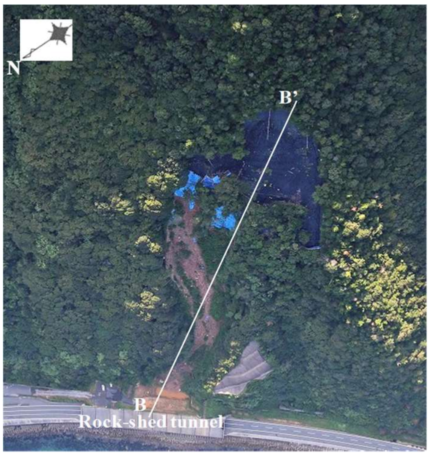
Landslides induced by heavy rainfall are one of the most destructive natural hazards. It often causes serious disaster, such as loss of the social prosperity, human life, etc. Several failures have occurred at an unstable steep slope in Yamaguchi prefecture over the last 20 years. According to the long-term field measurements, large displacements occurred when the groundwater level increased after rainfall (Nakashima et al., 2018). In order to understand the mechanism of the occurrence of large displacements, numerical analyses are conducted in this study.

2. NUMERICAL SIMULATIONS

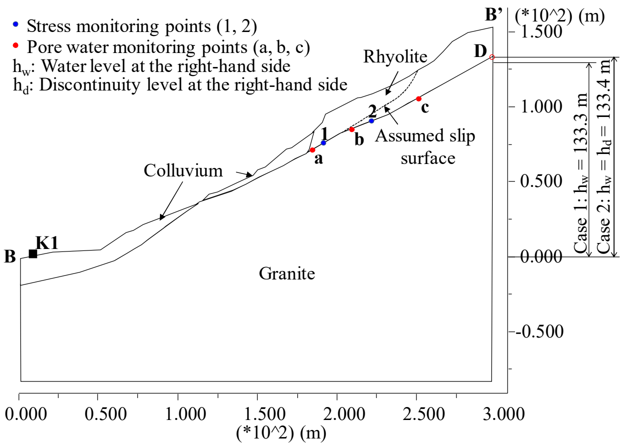
2.1 Outline of slope and numerical modeling

The slope is composed of rhyolite and granite. Its surface is covered by colluvial deposits. Since the slope has been gradually failed over the last 20 years, a check dam and a rock-shed tunnel was constructed to protect the road. Fig. 1 shows a panoramic view. The vertical cross-section BB' is selected to simulate the slope behavior for two-dimensional analysis by the Distinct Element Method, UDEC (Itasca, 2014). The mechanical properties of rocks and discontinuities are listed in Table 1.

The procedure of the analysis is as follows: (1) the initial model is built as shown in Fig.1(b), (2) gravity is applied to conduct analysis at first, (3) the groundwater level is assumed to increase to the height of the discontinuity (see the right-hand boundary of the domain of analysis in Fig.1(b)). The water level and the discontinuity level (point D in Fig. 1(b)) above the slope toe at the right-hand side are denoted by h_w and h_d, respectively.



(a) Panoramic view



(b) Cross-section BB'

Fig. 1 Slope site

Table 1 Mechanical properties of rocks

Parameter	Colluvium	Rhyolite	Granite
Density (kg/m^3)	2500	2500	2500
Elastic modulus (MPa)	580	1000	9000
Poisson's ratio	0.3	0.3	0.2

Discontinuity

Normal stiffness, j_{kn} (MPa/m)	Shear stiffness, j_{ks} (MPa/m)	Friction angle, j_{fric} (degree)	Cohesion, j_{coh} (MPa)	Permeability factor, j_{perm} (1/Pa. sec)	Residual hydraulic aperture, a_{res} (mm)	Aperture at zero normal stress, a_{zero} (mm)
1.0x10^3	1.0x10^3	16.5	0.1	100	0.2	0.5

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This study considers two cases of the water level: case 1 is h_w = 133.3 m (10 cm just below the discontinuity point D), and case 2 is $h_w = h_d$ = 133.4 m (at the point D). Stress and pore pressure are calculated at points 1 and 2, and a, b, and c on the discontinuity (the boundary between rhyolite and granite), respectively.

2.2 Results and discussions

Fig. 2 shows the pore pressures at the points a, b, and c (see Fig.1(b)). When the water level is lower than the discontinuity point D at the right-hand side boundary (case 1), the pore pressures are zero at all points. When the water level comes up to the discontinuity point D (case 2), the pore pressure increases significantly at all points.

Fig. 3 represents the stress path at the points 1 and 2. It is found that the stress states at the both points 1 and 2 do not reach at the failure criteria when the water level in the right-hand side is lower than the discontinuity point D (case 1). On the other hand, the water level at the right-hand boundary comes up to the discontinuity point D (case 2), the stress reaches the failure criteria. And then, the slip occurs on the boundary between rhyolite and granite. Eventually, it leads a large displacement of the upper block as shown in Fig.4.

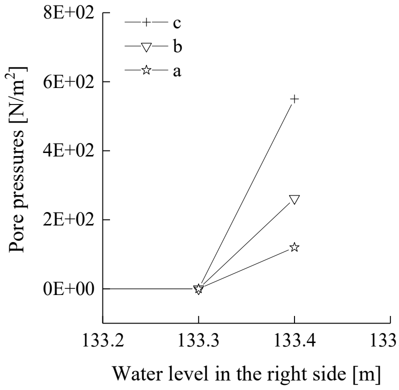


Fig. 2 Pore pressures at points a, b, and c (see Fig. 1)

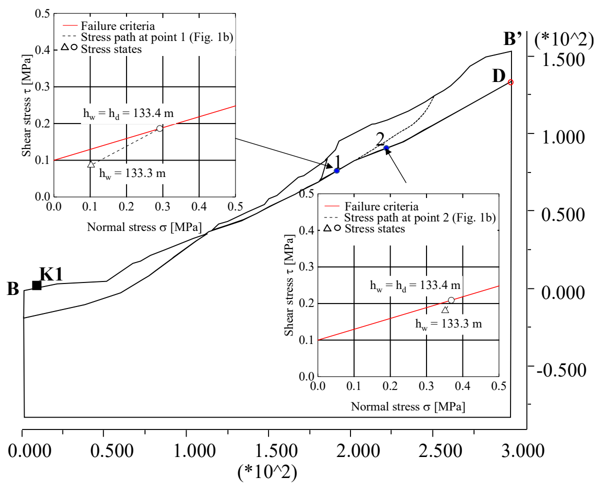
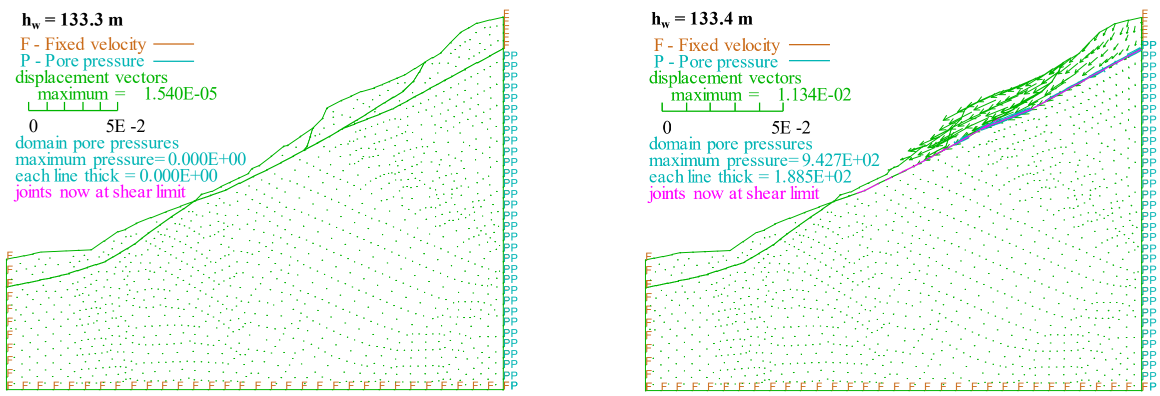


Fig. 3 Stress path at points 1 and 2 on the boundary between rhyolite and granite



(a) Case 1: h_w = 133.3 m (b) Case 2: $h_w = h_d$ = 133.4 m

Fig. 4 Displacement distribution

3. CONCLUSIONS

The failure mechanism of a steep slope has been discussed by numerical simulations. The numerical analysis was successfully conducted to reveal the mechanism of the landslide behavior. It is found that the increase of the groundwater level is a trigger to occur the large displacements in this slope.

REFERENCES

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