第Ⅲ部門　　Behaviors of an undercut slope with a plane of discontinuity studied by centrifuge model

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1. Introduction and background

Previous researches have shown an acceptable agreement between the theoretical idealization and the experimental results of 1g physical model with a plane of discontinuity (Techawongsakorn et al. (2016)); however, 1g model test might not be convincible due to its limitation on low stress level. So a centrifuge model is conducted to observe the behaviors and compare with 1g physical model. This paper reveals on the comparison of failure modes and their behaviors before the onset of failure. Two main assumptions of failure mechanism i.e. arch failure and beam failure assumptions are summarized hereafter.

1) Arch failure assumption: Pipatpongsa et al. (2013) derived Eq. (1) to predict the maximum width of undercut slope under arch failure for which the arching coefficient k=1 where B_f is the maximum stable width, α is the inclined angle, T is the thickness of soil block, ϕ_i is the interface friction angle, c_i is the apparent adhesion, σ_c is the unconfined compressive strength, γ is the bulk unit weight, ϕ is the internal friction angle of material.

$$B_f = \frac{k}{(\sin\alpha - \tan\phi_i \cos\alpha) - (c_i/\gamma T)} \frac{\sigma_c}{\gamma} \tag{1}$$

2) Beam failure assumption: The maximum width of undercut slope for beam failure can be predicted by Eqs. (2)−(4). The assumption and parameter description are described in detail by Techawongsakorn et al. (2016).

$$M_p = T\frac{h}{2} = \frac{1}{2}bh^2\frac{a}{1+a}\sigma_c \text{ where } a = \frac{1-sin\phi}{1+sin\phi}\ ,\ w = \gamma Ts\left(sin\alpha - tan\phi_i cos\alpha - \frac{c_i}{\gamma T}\right),\ B_f = 4\sqrt{\frac{M_p}{w}} \quad (2), (3), (4)$$

2. Methodology

The physical models of two cases, no plane of discontinuity and a plane of discontinuity, were made of Edosaki sand. Basic properties of Edosaki sand (Khosravi et al., 2016) are, unconfined compressive strength 14.7 kN/m^2, interface friction angle 17.5°, apparent adhesion 0 kN/m^2 and internal friction angle 40.9°. The model was divided into two parts, the basal support and slope part; each of which was compacted to the bulk unit weight 15.3 kN/m^3 and water content 10%. The 20 cm wide, 17.5 cm long and 5 cm thick basal support was placed on sand paper while the 20 cm wide, 22.5 cm long, 5 cm thick slope part was inclined by angle 40°on a Teflon plate for simulating the low friction interface plane. Pressure gauges were installed in the slope part during the compaction shown in Fig. 1. A discontinuous plane was inserted on the slope part at 3 cm above the undercut width by using rounded spatula blade in normal direction to the slope. The trapezoidal trench was excavated through the basal support to have a base width of 10 cm and a top width of 12 cm as shown in Fig.2. Finally, the marking lines were drawn on the surface every 5 cm from bottom of the slope part for clear observations.

3. Results and discussions

For no plane of discontinuity, test no.1, substituting the parameters into Eq. (1), B_f = 2.39 m in the prototype scale. This is equivalent to 21.7g in the centrifuge model under average maximum stable width of sand block 11 cm. After using centrifuge model test, failure is observed at 31.4g like arch failure as shown in Fig.3. For a

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plane of discontinuity, test no.2, also substituting the parameters into Eq. (2), (3) and (4), B_f = 0.32 m in the prototype scale. It is equal to 2.9g in the centrifuge model. Failure is observed at 30.2g in centrifuge model test which is totally different from the theory. Therefore, increasing gravitational acceleration in centrifuge model does not induce to occur beam failure. The slopes with discontinuous planes in 1g test tend to develop beam failure by relative displacements (Techawongsakorn et al. (2016)) but it does not seem to happen the same behaviors in centrifuge model. In centrifuge model test, the span of undercut slope is probably not long enough to induce tension which bends the soil block to cause tension cracks, following beam failure. Another reason, the plane of discontinuity was closed as shown in Fig.4 comparing to Fig.2 by the downward movement of upper portion of the slope while basal support braces the lower portion of the slope. Consequently, the model cannot maintain the discontinuous condition; thus, the relative displacement did not significantly occur.

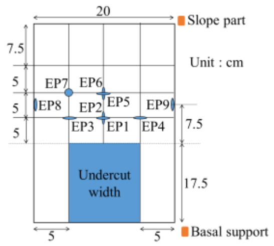

Fig.1 Location of gauges

Fig.2 Physical model

Fig.3 Failure mode Test 1

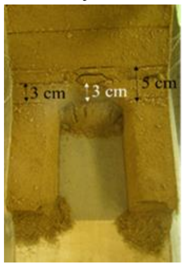

Fig.4 Failure mode Test 2

During the centrifuge test, the pressure gauges were monitored and recorded. These data were normalized by ρgT and plotted with time in Fig.5 and 6 respectively for model test no.1 and 2. By increasing the gravitational force, each pressure gauge starts to increase the earth pressure. For test no.1, it shows the development of passive arch action as reported by Khosravi et al. (2016). For test no.2, earth pressures just increase gradually by increasing the gravitational force with no significant change. After failure occurs, only EP2 shows little change in earth pressure as shown in Fig.6. So, the failure can be considered as a local failure.

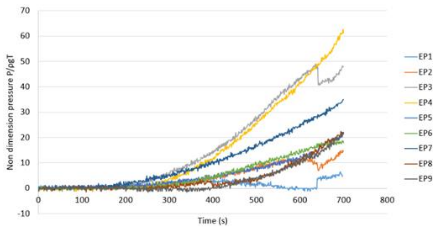

Fig.5 Changes of earth pressure in Test No.1

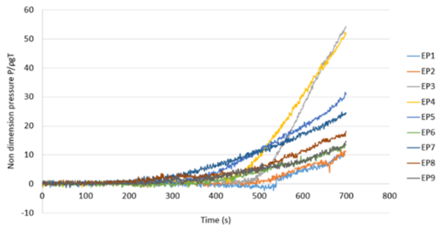

Fig.6 Changes of earth pressure in Test No.2

4. Conclusion

Failure mode and stress distribution of an undercut slope with a plane of discontinuity observed in centrifuge model are different from 1g physical model. For a continuous slope model, the centrifuge model gave a reasonable result. However, local failure of slope occurred in a discontinuous model instead of beam failure. More investigations are required to clarify this unclear results by either changing material or slope dimension.

References

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