Deformation Characteristics of Sandy Clay during Slope Excavation

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1. Introduction

Centrifuge modeling in combination with a digital image analysis technique was performed to evaluate two-deformational displacements such as maximum shear strain distribution of sandy clay soil during the slope excavation. The centrifuge test was conducted using the Mark-II centrifuge at the Japan National Institute of Occupational Safety and Health, which is capable of simulating both of dynamic and static geotechnical problems.

2. Model preparation

The model test was performed in a rigid model box with transparent Plexiglas sidewall to enable side viewing of the model during centrifuge flight. The internal dimensions of the rectangular model box are 150×450×272 mm. The sandy clay ground model was prepared by mixing Toyoura sand and Kaolin (NSF clay) as a ratio of 3:1 by weight at 10 % water content. The mixture was then placed into the model box and compacted in 13 layers (20 mm thickness per layer) under a pressure of 50 kPa by the bellofram cylinder. The unit weight after the compaction was about 15 kN/m^3. The resulting block of ground model was trimmed to form the slope geometry. Figure 1 shows a schematic view of the experimental model and arrangement of linear variable displacement transducers (LVDTs). In order to observe the deformations of the slope during centrifuge test, a grid-printed membrane was set between the transparent sidewall and the ground model. The friction between the sidewall and the membrane was reduced by smearing the sidewall surface with silicon grease. The digital video and CCD cameras were mounted directly in front of the model box, which is capable of providing a continuous record during testing. The resolution and physical size of the image acquired by the CCD camera was 1600×1200 and 560×420 mm, respectively, thus the resolution is approximately 0.35 mm per pixel.

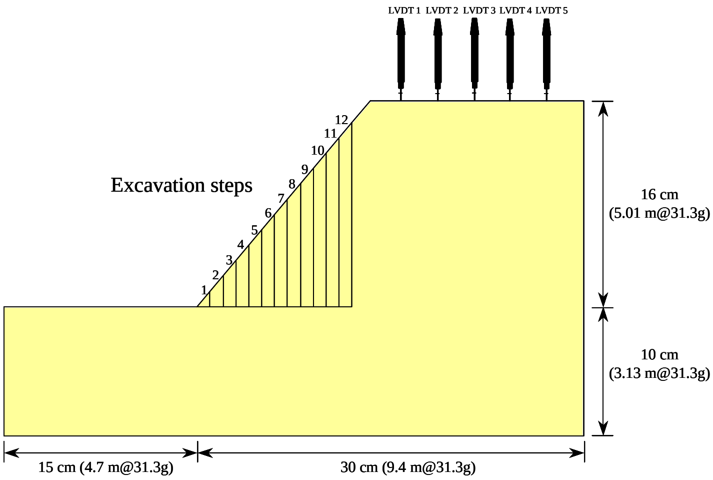

Fig. 1. The experimental slope model

3. Simulation of slope excavation

After the model box was loaded onto the centrifuge payload platform, the centrifuge acceleration level was gradually increased in steps of 5g after there was no variation in surface settlement observed from the displacement transducers. The in-flight slope excavation was conducted at the centrifuge acceleration of about 31.3g where the height of slope was 5 m corresponding to the prototype scale. The NIIS in-flight excavator, which can excavate the model ground vertically during the high centrifuge acceleration environment, was used in this paper for simulating the slope excavation process. The detail of the NIIS in-flight excavator was described by Toyosawa et al. (1998). The movement of the in-flight excavator was controlled manually from the computer room, the slope model was excavated step by step as shown in the Fig. 1 until the failure of slope can be observed.

Keywords: image analysis, centrifuge, slope excavation

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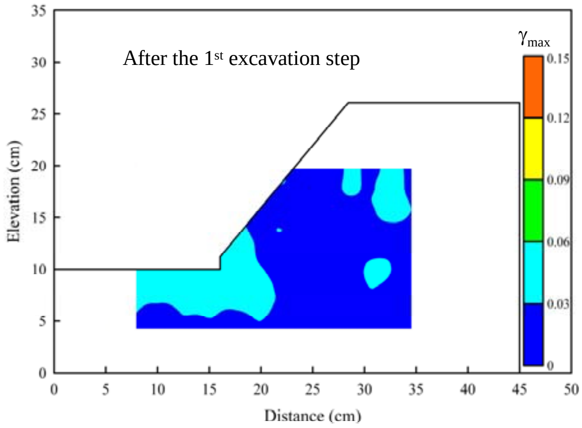

Fig. 2. Distribution of γ_{max} after the 1st excavation

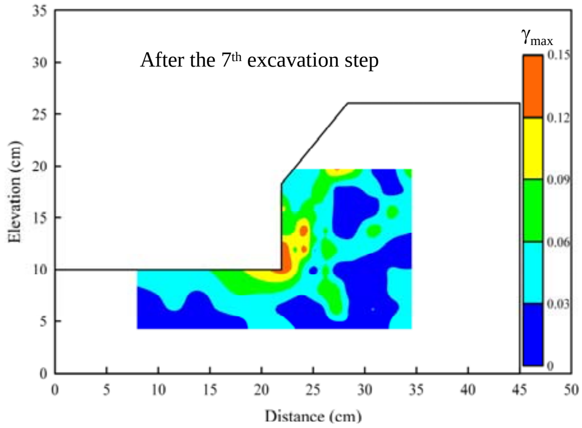

Fig. 4. Distribution of γ_{max} after the 7th excavation

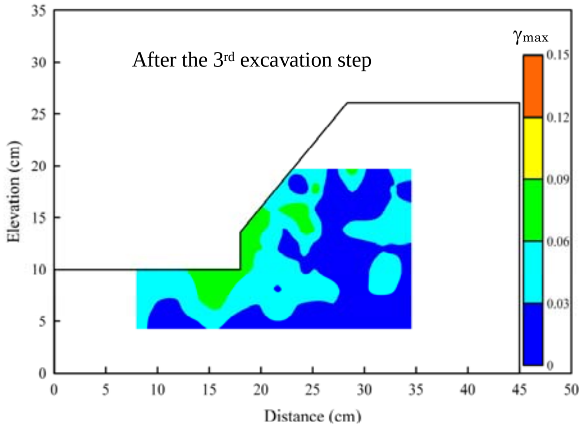

Fig. 3. Distribution of γ_{max} after the 3rd excavation

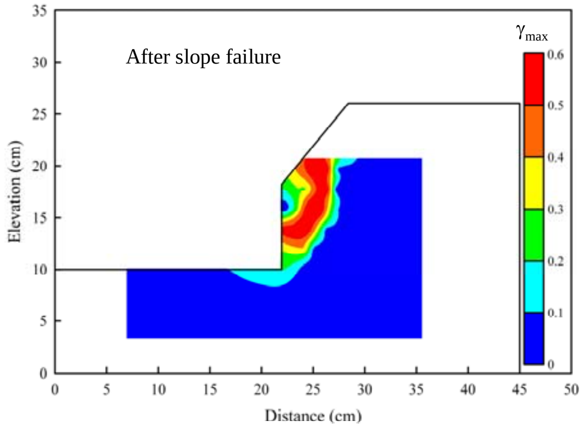

Fig. 5. Distribution of γ_{max} just after the failure

4. Test results

The failure of slope was clearly observed after the 7th excavation step. The two-dimensional deformations of the ground model can be evaluated by measuring the displacements of grid-printed membrane captured by taking photographs after each step of the in-flight excavations. Each rectangular grid was divided into two triangles, and the Lagrangian strains on these two triangles were averaged and then used to compute the engineering strain. Figures 2 to 5 show the distribution of the maximum shear strain ($\gamma_{max} = \varepsilon_1 - \varepsilon_3$) after the 1st, 3rd, 7th excavation steps and just after slope failure, respectively. It should be noted that the separations of the maximum shear strain contours in the figures were due to the limited boundaries of the Plexiglas sidewall where the targets outside the Plexiglas sidewall cannot be identified. As can be seen in the figures, after each excavation step the progressive failure can be observed from the toe toward to the upper part of the slope. Figure 6 shows the photograph of the slope failure, the observed failure plane was found in good agreement with the distribution of the maximum shear strain.

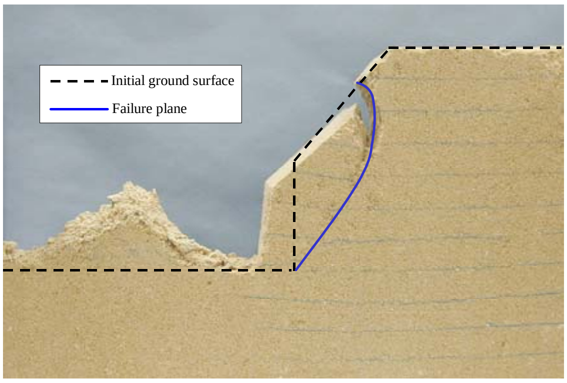

Fig. 6. The location of failure plane

5. Conclusions

The centrifuge modeling in combination with the digital image analysis made it possible to evaluate quantitatively the two-dimensional deformation characteristics of sandy clay soil during the slope excavation.

Reference

Toyosawa, Y., Horii, N., and Tamate, S. (1998). Deformation and failure behaviour of anchored retaining wall induced by excessive excavation in centrifuge model tests. Research reports NIIS-RR-97, p.35-46.