Multi-stage failure simulations for rock mass failure

Kenjiro Terada[1], Shuji Moriguchi[2] and Shun Suzuki[3]

1. Research interests

The main thrust in our research is the exploration of numerical methods for failure simulations of slope disasters involving multiple stages. For example, when we are concerned with slopes with brittle materials and structures, the failure phenomenon must involve the following three stages:

1) At the first stage: a structure deforms in response to dynamic or static excitations and displays cracks along prescribed discontinuities so that it would be separated into several blocks.
2) At the second stage: several sets of blocks lose static equilibria and start to move dynamically.
3) At the third stage: moving blocks collide each other with friction and some of them further break up due to the shock generated by the collision.

To simulate this three-stage failure process involving large deformation and rotations with dynamic frictional-contact behavior, we have developed a new numerical method based on the co-rotational finite element formulation [1,2]. The proposed method is designed to simulate all of these deformation and failure stages in a continuous fashion. In order to represent dynamic frictional contact with large rotations after the crack propagation, we incorporate the effects of dynamics, gluing, and contact within the framework of the co-rotational theory [3,4]. To validate the proposed method, we have been trying to simulate the collapse of a slope involving collision followed by segmentation by cracking.

Fig. 1 illustrate the finite element model for to simulate a slope sliding failure of a rock mass with potential discontinuities. Here, the slope is subjected to the seismic motion caused by the enforced displacement to the bottom of the model and is considered to fail at a certain time after the excitation. This displacement wave is obtained by transforming from the acceleration wave-form observed in the 2016 Kumamoto earthquake. Fig. 2 shows the sequence of the deformed configurations of the rock slope. The blocks that are initially glued together separate and the resulting crack surfaces contact with each other. It is safe to conclude that the rock slope failure could be successfully simulated by the proposed method that is capable of representing the large rotation with frictional contact behavior.

2. Perspectives for collaboration

Since suitable experimental data is insufficient for the validation of the proposed method, possible collaborators in UW would be those who can provide some experimental data of slope failures. Simple experiments are enough to demonstrate its capability of multi-stage failure. Or rather, we welcome case examples of slope failures that were actually occurred in US and/or Japan.

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The other contributors are: Yosuke Yamanaka[a], Norio Takeuchi[a] (a:Tohoku University; b: Hosei University)

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[1] Professor, International Research Institute of Disaster Science, Tohoku University, Japan (tei@irides.tohoku.ac.jp)
[2] Associate Professor, International Research Institute of Disaster Science, Tohoku University, Japan (s_mori@irides.tohoku.ac.jp)
[3] Graduate Student, Department of Civil and Environmental Engineering, Tohoku University, Japan (shun.suzuki.q7@dc.tohoku.ac.jp)

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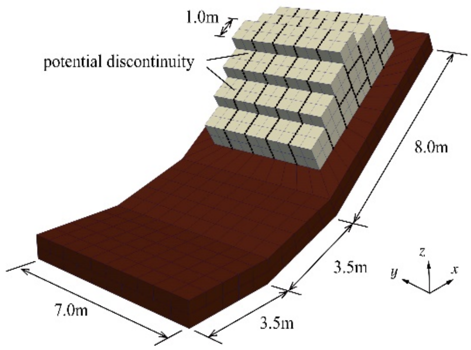

Fig. 1 Finite element model for analysis of a rock slope failure with potential discontinuities.

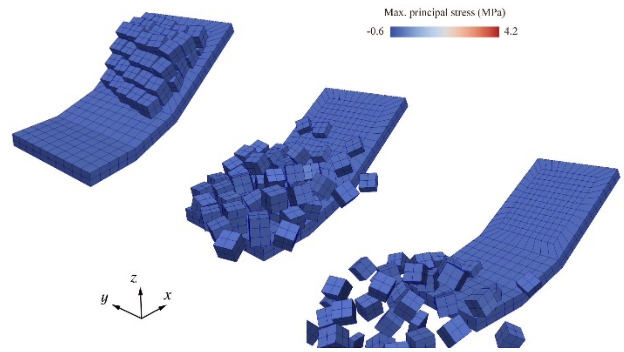

Fig. 2 Sequence of deformed configuration with maximum principal stress distribution