Development of New Implicit Discrete Element Analysis Method Based on Finite Deformation Theory

Shun, Suzuki*, Kenjiro Terada†, Shuji Moriguchi‡ and Nrio Takeuchi§

* School of Engineering, Tohoku University
Aza Aoba 468-1, Aramaki, Aoba-ku, Sendai 980-8572, Japan
e-mail: shun.suzuki.q7@dc.tohoku.ac.jp - Web page: http://www.cae.civil.tohoku.ac.jp

† International Research Institute of Disaster Science (IRIDeS), Tohoku University
Aza Aoba 468-1, Aramaki, Aoba-ku, Sendai 980-8572, Japan
Email: tei@irides.tohoku.ac.jp - Web page: http://www.cae.civil.tohoku.ac.jp

‡ International Research Institute of Disaster Science (IRIDeS), Tohoku University
Aza Aoba 468-1, Aramaki, Aoba-ku, Sendai 980-8572, Japan
Email: s_mori@irides.tohoku.ac.jp - Web page: http://www.cae.civil.tohoku.ac.jp

§ Department of Engineering and Design, Hosei University
2-33 Ichigayatamachi, Shinjuku-ku, Tokyo 162-0843, Japan
Email: takeuchi@hosei.ac.jp

ABSTRACT

In this paper, we propose a new discrete analysis method based on finite deformation theory within finite element framework in order to simulate failure process of a discontinuous rock slope.

The energy-momentum method[1)] is adopted to deal with the dynamic behaviour. This approach imposes the equivalence between the change of total momentum of the system and the impulse of the external forces acting on the system during each time step. In addition, this method exhibits the proper energy balance within a time interval so that unconditional stability in time can be realized. Here, we formulate a positive energy dissipation with plastic deformation which represents mechanical characteristic change of rock mass. This dissipative inequality is able to construct exact energy consistent involving internal dissipation so that we can update the proper deformation in consideration of material characteristic change.

The selective activation approach[2)] is applied to simulate the motion of discrete blocks within finite element framework. With this method, each finite element is initially glued with multi-point constraints, and some of them separates to sets of blocks when fracture occurred. Therefore, selective activation of cohesive elements provides a progressive failure behaviour effectively. Also, the so-called node-to-surface approach is used to the discretization technique for non-matching meshes of blocks. The blocks are supposed to reduced energy due to dynamic frictional contact[3)] behaviour based on Coulomb friction law.

Verification tests are conducted for the formulation with a simple structure subjected to the large displacements and rotations. Also, some simple numerical examples are presented to demonstrate the capability of the proposed method to simulate the rock slope failure.

REFERENCES

[1] J. C. Simo and N. Tarnow, “The discrete energy-momentum method. Conserving algorithms for nonlinear elastodynamics”, *Z. angew. Math. Phys.*, **43**, 757-792 (1992).
[2] K. Woo and D. S. Cairns, “Selective activation of intrinsic cohesive elements for fracture analysis of laminated composites”, *Composite Structures*, **210**, 310-320 (2019).
[3] G. R. Love and T. A. Laursen, “Improved implicit integrators for transient impact problems—dynamic frictional dissipation within an admissible conserving framework”, *Comput. Methods Appl. Mech. Engrg.*, **192**, 2223-2248 (2003).