Author Version: Fujii, Y., Kodama, N. and Keppetipola, S. (2012), Mechanisms of Falling Rock Formation at Steep Slope due to Temperature Perturbation, Proc. MMIJ Spring Meeting, pp. 143-144, Mar. 27, Tokyo, JAPAN（資源･素材学会春季大会講演集、pp. 143-144、東京、2012, 3/27）

Mechanisms of Falling Rock Formation at Steep Slope due to Temperature Perturbation

Fujii, Y., Hokkaido Univ., Kodama, N., Hakodate Natl. College Tech. & Keppetipola, S., Hokkaido Univ.

1. Introduction

Rock falls can be seen at steep rock slopes and some of them result in physical and human damages. Mechanisms of rock fall occurrence should be clarified for reasonable prediction and prevention. Not fully clarified yet but a rock beam near rock surface can be formed either by weathering due to water-mineral chemical reactions, subcritical fracture growth due to rock stress, formation of ice lenses due to segregation freezing, intrusion of tree roots or thermal deformation. Rock beam should break at its bottom to fall but the mechanism for the breakage is unknown. This study aims to propose a mechanism of the breakage of rock beam at its bottom as well as to clarify the mechanism of the rock beam growth due to thermal deformation.

2. Numerical model

To complete the objectives, deformation of a steep rock slope with a fracture (Fig. 1) due to change in surrounding air temperature was numerically analyzed. Rock was assumed to be saturated and thermal deformation of rock, pore water and its freezing were considered. Pressure, migration and segregation freezing of pore water were not considered.

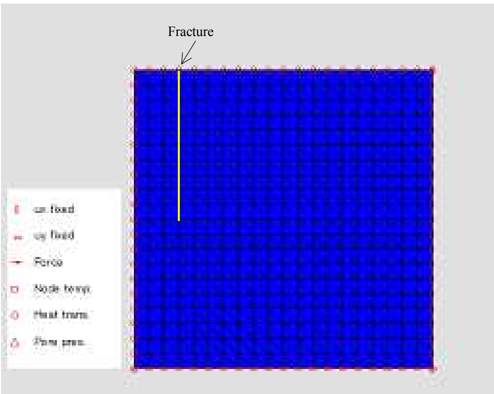

Fig. 1 An 1 m x 1 m x 1 m steep rock slope model having an 1 m long and 0.3 m thick vertical fracture. Normal displacements to the right and the bottom boundaries were confined. Heat transmission coefficient at the top and the left boundaries were set at 3 W/m^{2}K.

3. Results

In the case where the air temperature dropped from 40°C to 10°C, the fracture opened and tensile stress which can elongate the fracture appeared (the red arrow in Fig. 2). In the case where the air temperature dropped from 10°C to –20°C, the fracture closed with freezing expansion of beam surface. The fracture closure was prohibited after complete closure and the bending tensile stress which can break the rock beam appeared (Fig. 3).

In the case where the air temperature rose from 10°C to 40°C, the fracture closure was prohibited and the bending tensile stress appeared (Fig. 4). In the case where the air temperature rose from –20°C to 10°C, the fracture first opened with shrinkage of beam surface due to thawing and the tensile stress appeared (Fig. 5), and then the bending tensile stress appeared after the completion of thawing of the rock beam.

4. Concluding remarks

The above findings may qualitatively explain the mechanism of fracture deformation at steep rock slopes. For example, a fracture at a steep chert slope in the accretion prism in Japan closed certain amount with temperature drop below the freezing point in the early January, then became almost constant probably because of a full closure in the middle January, and opened with temperature rise above the freezing point in the late January (Fig. 6).

The tensile stresses can appear many times with change in air temperature and cause subcritical or fatigue fracture growth and can be one of the mechanisms of growth of rock beams at steep rock slopes. The bending tensile stress also can cause breakage of rock beam by simple tensile failure or either subcritical or fatigue crack growth. Fracture growth and beam breakage would be enhanced if the temperature varied across the freezing point even if the rock damage by the freeze-thaw cycle was not directly considered. These findings can contribute for deeper understanding of falling rock formation.

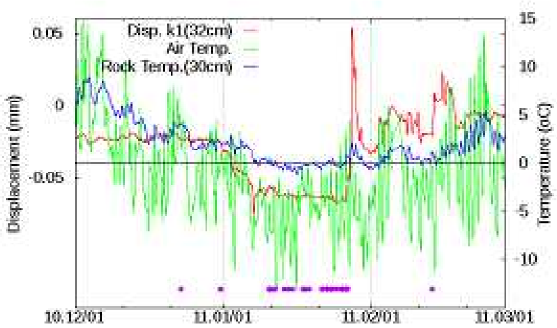

Fig. 6 Displacement of a rock fracture 0.3 m from the surface of steep slope due to temperature perturbation with air and rock temperature. Purple dots denote AE events.

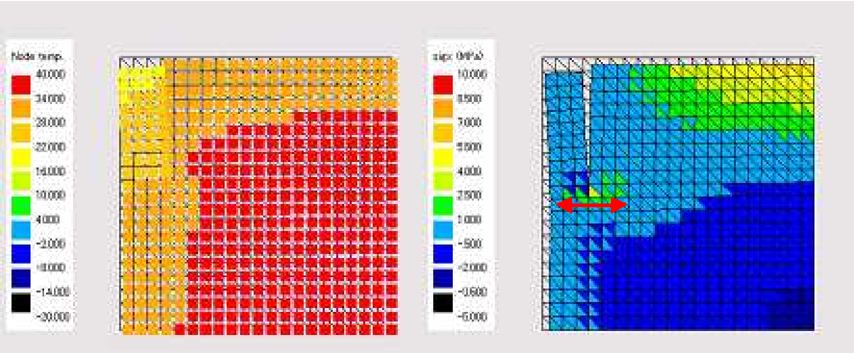

Fig. 2 Distribution of temperature (left) and σ_x (right), 67 hours after the air temperature change from 40°C to 10°C. Deformation was magnified by 500 times.

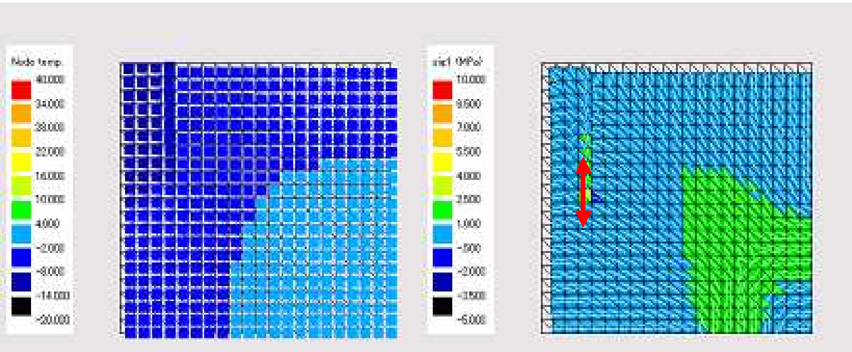

Fig. 3 Distribution of temperature (left) and σ_1 (right), 200 hours after the air temperature change from 10°C to −20°C. Deformation was magnified by 500 times.

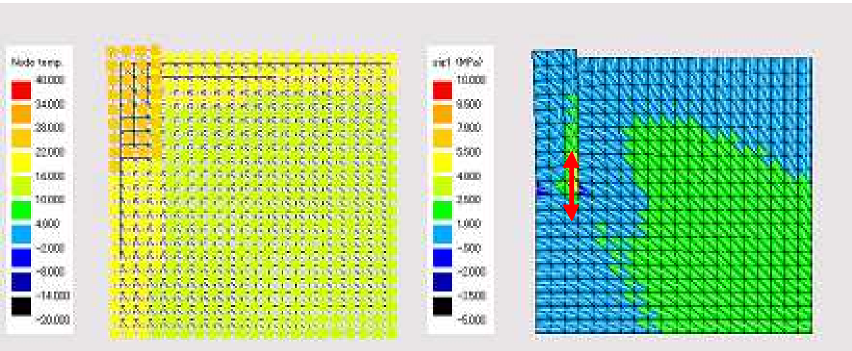

Fig. 4 Distribution of temperature (left) and σ_1 (right), 55 hours after the air temperature change from 10°C to 40°C. Deformation was magnified by 500 times.

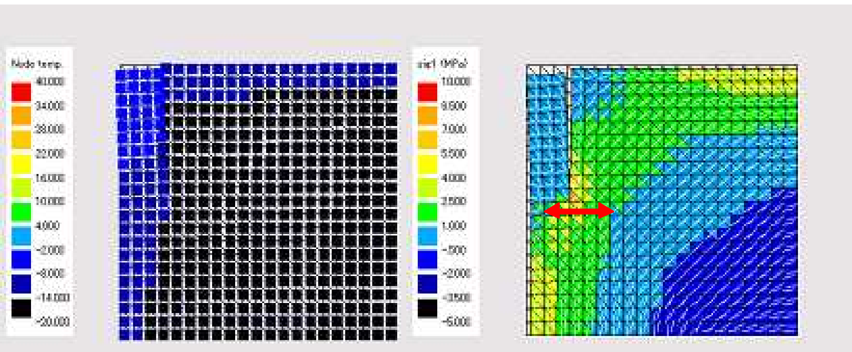

Fig. 5 Distribution of temperature (left) and σ_1 (right), 47 hours after the air temperature change from −20°C to 10°C. Deformation was magnified by 500 times.