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# Modelling of Rock Cracking Using Expansion of Vermiculite

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## ABSTRACT

Conventional excavation methods, such as drilling and blasting, are widely used for tunneling. However, the blasting process induces stress waves propagated through the ground, and subsequently, vibration and noise may occur at the ground surface. A new vibration-free excavation method using expansion of vermiculite is developed for rock cracking (Ahn and Hu 2015). The objective of this study is to evaluate the performance of vibration-free excavation method using the expansion of vermiculite according to rock condition. Rock block and expansion of vermiculite in a drilled hole are simulated using finite element method. The results of finite element analysis demonstrate that the vermiculite can be effectively used for rock cracking.

## 1. INTRODUCTION

Tunnel and underground space in urban area are often constructed for the efficient urban development. For the tunnel and underground space, various excavation methods have been used. The drilling and blasting process is one of the conventional excavation methods widely used for tunneling. In the blasting process, detonation pressure generates, and the blast-induced stress wave then propagates through the ground. Consequently, vibration and noise occur at the ground surface, often causing public complaint and the delay of construction process. To mitigate the blast-induced vibration, controlled blasting methods using empty drilling holes have been applied to the tunnel perimeter (Park et al. 2009). Although the line-drilling methods applied to the tunnel perimeter may reduce the blast-induced vibration, the blast-induced stress wave still can propagate through the area between the empty drilling holes.

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A new vibration-free excavation method using expansion of vermiculite was developed for rock cracking (Ahn and Hu 2015). Heating the vermiculite, its volume can increase up to 20 times (Ahn and Hu 2016). Although the vermiculite is a promising expansion material for rock cracking, the performance of vibration-free excavation method according to rock condition has not been properly investigated yet. Thus, this study presents the performance of vermiculite-based expansion system according to rock condition based on the numerical analyses.

## 2. Expansion Characteristic of Vermiculite

Vermiculite is a hydrous phyllosilicate mineral with shiny flakes. The vermiculite is formed by weathering or hydrothermal alteration of biotite (Rashad 2016). When the interlayer water in vermiculite is heated, the vermiculite can be expanded. Fig. 1 shows two vermiculite particles before and after the expansion, respectively. After heating, the volume of vermiculite can be expanded up to 20 times compared to its original volume. Using its expansion characteristic, the vermiculite was applied for cracking a rock block as a vibration-free excavation method (Ahn and Hu 2015; Ahn and Hu 2016). In the previous studies, the internal pressure at cracking corresponds to approximately 160 MPa.


Fig. 1 Expansion of vermiculite by thermal energy (Ahn and Hu 2016)

## 3. SIMULATION

In this study, the rock block investigated in the previous study was simulated by using finite element method. Fig. 2 shows the modeled rock block which had a dimension of 50 cm length, 50 cm width, and 50 cm height. For modelling installation of vermiculite and heater, a cylindrical hole with 5 cm diameter and 30 cm depth was located at the center of the rock. The rock block consists of cubic elements with 1 cm length. The bottom of the model was fixed to avoid the rigid body motion. The internal pressure of 160 MPa which was determined at the previous study was applied to the perimeter of the hole.

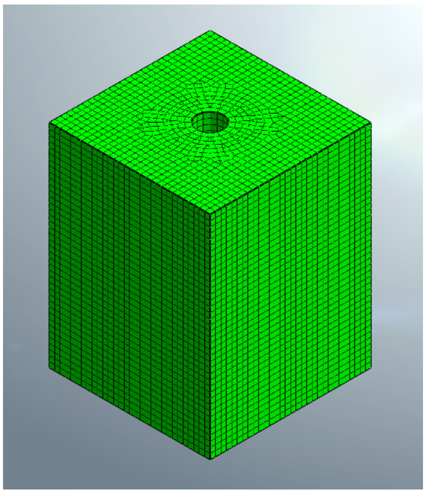

Fig. 2 Modeling of rock block

Fig. 3 shows the plan view of principal strain distribution within the rock block after applying the internal pressure of 160 MPa to the hole. The principal strain varies according to the distance from the center of the hole. The maximum principal strain of 0.005 occurs around the circumference of the hole, and the principal strain decreases with increasing the distance from the center of the hole. Fujii et al. (1998) reported that the principal tensile strain of 0.005 is at critical state of rock specimen, and the value can be used as a failure criterion of rock. Based on the failure criterion, it was found that the modeled rock block cracked, which was in agreement with the experimental results reported in previous studies. Note that the positive sign in principal strain indicates tensile strain.

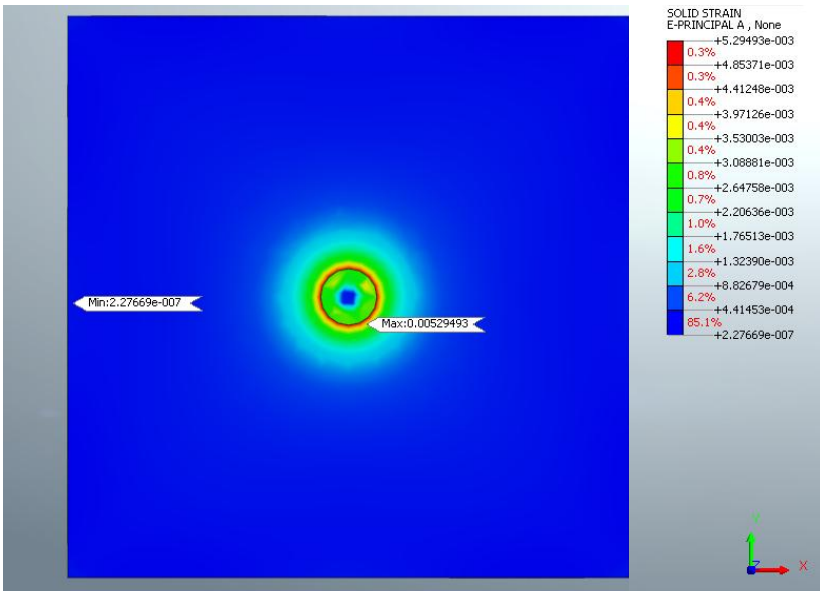


Fig. 3 Principal strain distribution in rock block with a width of 50 cm

## 4. CONCLUSIONS

The need of constructing tunnel and underground space are increasing, and various excavation methods, such as drilling and blasting process, have been used. Recently, a new vibration-free excavation method using expansion of vermiculite was developed for rock cracking. Vermiculite is an expansible material when heated. In previous studies, using vermiculite with heater was introduced for rock cracking. In this study, the principal strain distribution caused by the expansion of vermiculite was investigated by using finite element method. It was found that the rock cracking by the expansion of vermiculite was adequately simulated, based on a failure criterion by the principal tensile strain.

## ACKNOWLEDGEMENT

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