Study on the Stability of Underground Cavity and Countermeasures for Safe Mining Operation in Limestone Quarry

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1. Introduction

Currently, more than 200 limestone quarries are in operation in Japan and a bench cut method is mainly applied as a mining method. In general, as most of the mines are located in the mountain regions with a steep slope, the limestone ore excavated from a working bench at a high elevation is thrown into the shaft to achieve efficient transportation by utilizing the gravity. In case that the fracture zone is dominant in the rock mass of limestone quarry, a collapse of rock mass around the shaft often occurs and then the underground cavity is formed in some cases. As the mining operation proceeds and the distance between the bottom of bench and the underground cavity becomes to be short, the stability of rock mass around the cavity and the bottom of the working bench is decreased and then the mining operation may be stopped. Therefore, in order to discuss the safety distance between the working bench and the underground cavity and countermeasures for safe mining operation, a series of numerical simulations are conducted by means of finite differential code “FLAC^{3D}”.

2. Numerical analysis

In this research, a numerical model is constructed based on the geological conditions determined by the observation of boring core samples and the results of laboratory experiments as shown in Fig. 1. This model consists of 7 parts and each part has different properties which are estimated based on Geological Strength Index (GSI). An underground cavity is also created in the fractured zone as a current situation. A series of numerical simulations were conducted in order to identify the effect of the level down of working bench on the stability of rock mass around the underground cavity and to discuss the effectiveness of backfilling method as a countermeasure for safe mining operation. The Mohr-Coulomb failure criterion is adopted to evaluate the stability the rock mass.

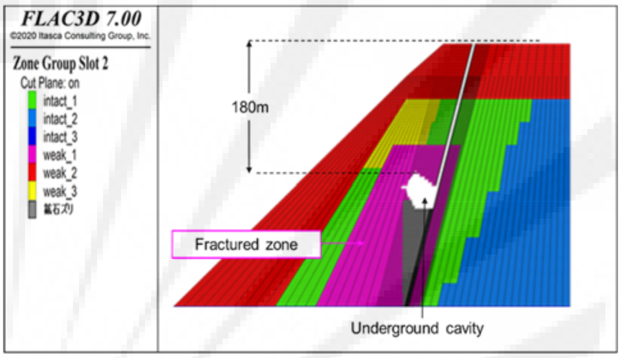
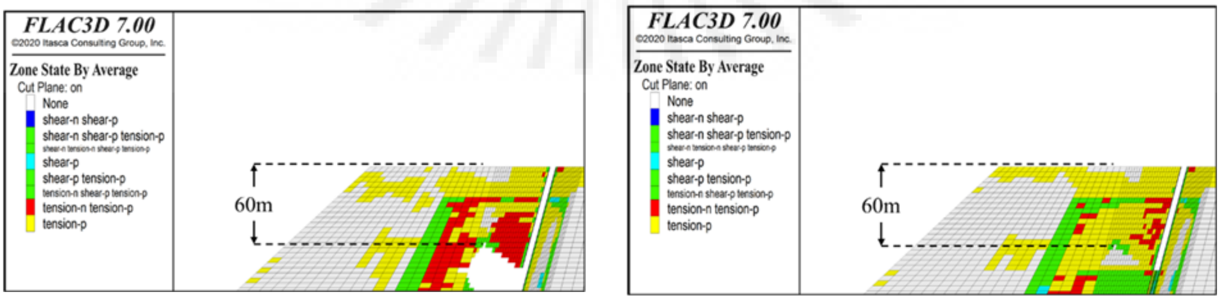


Fig.1 Numerical model (Cross section)

3. Results and discussions

Figs.2 (a), (b) show that the distributions of failure zones around the underground cavity with and without backfill, respectively. Here, limestone ore and grouting material which water-cement ratio is 50% are sed as a backfilling material. It can be found from both figures that the stability of rock mass around the underground cavity is improved dramatically as the cavity is backfilled and the mining operation can be conducted until the distance between the bottom of the pit and the crown of the cavity is 60 m or less. However, even though the underground cavity is backfilled, it is necessary for the safe mining operation to observe the conditions of the underground cavity and the surrounding rock mass carefully as the mining operation proceeds.



(a) Without Backfill
(b) Backfilled with limestone ore and grouting material

Fig.2 Distribution of failure zone around the underground cavity
(Distance between the bottom of the pit and the crown of the underground cavity is 60 m)