学　位　論　文　内　容　の　要　旨

DISSERTATION ABSTRACT

博士の専攻分野の名称　　博士（工学）　　氏名　Najib

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Elastic deformation of rock slopes due to excavation in open pit mines

(掘削に伴う露天掘り鉱山の残壁の弾性変形の解析)

Stability assessment is an important issue for rock slopes in open-pit mining. Instability of rock slopes may result in slope failure, causing not only loss of production but also unexpected expense for rehabilitation. Furthermore, fatal accidents may occur due to rock slope failure, making slope monitoring critically important in open-pit mining. Displacement of a natural slope is usually caused by inelastic deformation; however, that of a cut rock slope in an open-pit mine may often be the result of elastic deformation due to excavation as well as inelastic deformation. For this reason, decomposing the measured displacement into elastic and inelastic components is necessary for a stability assessment. It has been shown that numerical analysis is powerful tool to estimate the elastic deformation due to excavation and that of cut rock slope in a homogeneous pit-type mine has been clarified. However, the deformation of rock slopes formed in a mountain-type mine has not been investigated in detail. In Japan, limestone deposit is often found on inclined bedrock and a part of limestone deposit is left on the bedrock as a buttress to prevent the bedrock from deterioration. Thus, understanding effects of both the inclined bedrock and buttress on rock slope deformation is also significant.

In this dissertation, a mining-induced elastic deformation of a cut rock slope formed in mountain-type and pit-type mines is estimated using a two-dimensional finite element method. Then, mode and mechanism of the elastic deformation were clarified considering effects of bedrock and buttress. Next, effective rock slope monitoring was suggested for stability assessment based on the estimated elastic deformation. Finally, rock slope deformation measured in Shiriya limestone mine was interpreted by elastic analysis.

The dissertation consists of six chapters.

In chapter 1, the background and purpose of this study were described and the literatures related to rock slope stability assessment in open-pit mines were reviewed.

In chapter 2, the fundamental deformation modes and its mechanism of homogeneous mountain-type mine were discussed in terms of the effects of the Poisson's ratio, slope angle and progression of the excavation. The results show that four effects contribute to the deformation mechanism in a mountain-type mine: Poisson effect (PE), distributed load effect (DLE), bending effect (BE) and shear distortion (SD). Forward surface displacement of the cut rock slope was found to occur during the early stages of excavation due to the release of horizontal compressive stresses due to BE. As the excavation progresses, either forward or backward horizontal surface displacement was found to occur due to PE or DLE, respectively, which depends on the Poisson's ratio. Asymmetric stress release due

to excavation affects the horizontal deformation of the mountain, and induces a moment enhancing the backward displacement due to SD.

In chapter 3, by focusing on mountain-type mines, the influence of difference in Young's modulus between limestone and bedrock on rock slope deformation was investigated. The effect of buttress of intact limestone was also investigated. It was found that deformation mode of the rock slope is always extension and independent of both Poisson's ratio and difference in Young's modulus with very few exceptions. It was also found that no significant difference in the deformation modes can be seen for the cases with or without the presence of the buttress, but the magnitude of the extended deformation decreased with increasing in thickness of the buttress.

In chapter 4, by focusing on pit-type mines, the influence of difference in Young's modulus between limestone and bedrock on rock slope deformation was investigated. The effect of buttress of intact limestone was also investigated. It was found that deformation mode when Young's modulus of limestone is greater than that of the bedrock is the same as the deformation mode in homogeneous case. The rock slope showed contracted deformation at small Poisson's ratio, but it showed extended deformation at high Poisson's ratio. In contrast, the rock slope always showed contracted deformation when Young's modulus of bedrock is greater. The effect of buttress in a pit-type mine was similar to that in mountain-type mines. Presence of the buttress only affects the magnitude of the rock slope deformation. The magnitude of the deformation decreased with increase in thickness of the buttress.

In chapter 5, deformation modes of rock slopes in both mountain-type and pit-type mines were summarized in a list for quick reference. Then, effective rock slope monitoring was considered for stability assessment based on the estimated elastic deformation. It may be concluded that the combination of monitoring the internal displacement using extensometers and the surface displacement using APS and/or GPS is powerful tool for stability assessment of cut rock slopes since the direction of both the surface displacement and internal displacement of the rock slope could change with the excavation progresses, even for a stable rock slope. Finally, rock slope deformation measured by extensometers in Shiriya limestone mine as one of pit-type mines were attempted to interpret by elastic analysis. It was shown that the deformations of rock slopes can be interpreted as being elastic by assuming difference in Young's modulus between limestone and bedrock.

In chapter 6, the obtained results were summarized and some future challenges were shown.