대절토사면과 인접한 터널갱구부의 붕괴사례연구

A Case Study of Collapse at Tunnel Portal adjacent to the Large Cut Slope

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Abstract

절토사면 및 천심도 터널의 경우 불연속면을 따른 블록의 미끄러짐 및 회전 등이 안정성에 큰 영향을 미친다. 국도나 지방도 등을 확장 공사함에 따라 산악이 많은 우리나라 지형의 특성상 절토사면이 많이 발생하게 되고, 경우에 따라서는 이러한 절토사면에 터널이 위치하게 된다. 이런 상황의 터널갱구부 및 인접한 절토사면부에서 붕괴 및 균열이 빈번하게 발생되고 있다. 본 연구에서는 대절토사면과 인접한 터널갱구부에 대하여 편토압이 균열의 주원인인지를 결정하기 위하여 변위 및 응력 패턴을 분석한 사례연구를 제시하였다. 조사대상지역은 울진군에 위치한 터널굴진 현장이고, 붕괴는 터널갱구부와 인접한 절토사면부에서 발생하였으며 터널갱구부 상단의 숏크리트 타설지역에서 다수의 균열이 관찰되었다. 언급한 터널갱구부의 변위 및 응력패턴을 모사하기 위하여 유한차분법에 근거한 플랙을 사용하였으며, 세밀한 수치해석을 위해 편재절리모델을 도입하였다. 마지막으로, 터널갱구부의 균열에 영향을 미친 주원인에 대한 고찰을 다루었다.

key words : 터널, 절토사면, 편토압, 플랙, 편재절리모델

1. Introduction

When expanding roads in mountainous areas, a number of cut-slopes and tunnels could be generated. In addition, when excavating tunnel in lower area of cut-slope, it is likely to excavate in the inclined area. Especially when excavating shallow depth tunnel, uneven pressure could be applied along with direction of slope and consequently it affects to stability of tunnel portal and adjacent cut-slope. This study tries to analyze whether or not the uneven pressure is critical to overall collapse by introducing rock mass classification methods and ubiquitous joint model.

2. Site Investigation

2.1 Outline

In order to evaluate the rock classification systems and ubiquitous joint model(Ub model), this study performed case study whose cut-slope are adjacent to tunnel under construction. 00 tunnel is surrounded by mountains, and valleys have been developed. The main dip/dip direction of schistosity on the cut-slope adjacent to the 00 tunnel is 60/040. Since dip direction of main faults is nearly perpendicular to the dip direction of the cut-slope, it is agreeable to say that cut-slope is stable if considering only dip directions. For the cut-slope adjacent to the 00 tunnel, length is 85 m (STA.7+020~7+105) and height is 45 m. Lower part of the first berm was collapsed, and several cracks were developed along with main schistosity on the surface near STA. 7+075. FRP grouting was reinforced by 2×2 spacing after cutting, and soil-nailing as well as shortcrete was applied to the upper part of tunnel portal. 00 tunnel was excavated up to total 7 meters to STA. 7+110. Overall hydraulic condition belongs to the 'flow' condition due to the valley and groundwater condition, and weathering level is highly weathered condition.

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(a) (b)

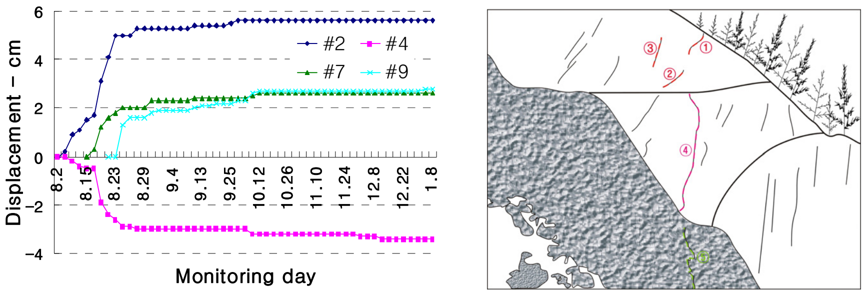
Figure 1. Cut-slope adjacent to the 00 tunnel(a) and diagram of collapsed pattern (b)

2.2 Cracks

Almost ten tension cracks were occurred at cut-slope adjacent to tunnel portal. We have performed instrumentation monitoring on the cracks in order to observe the displacement of cracks. Crack number 1~4 were observed on the surface above the forth berm between STA. 7+075~7+095, and number 5~7 were on the surface near the forth berm of shortcreted area above tunnel portal. Crack number 9 and 10 were inside of mentioned natural slope. To examine cracks' data closely, cracks started to converge after stopping tunnel excavation. As to development pattern of cracks, cracks number 5~7 of tunnel portal area were located on the extension line starts from cracks number 1~4 which developed in the left surface area of cut-slope. Except crack number 3, width of number 1,2, and 4 cracks was between 2~5 cm, and width of cracks number 5~7 was about 2 cm. That is, cracks on upper area of tunnel portal could be attributable to the expansion of cracks from left cut-slope, internal scour, or backward movement of weak zone rather than spontaneous expansion.

(a) (b)

Figure 2. Cracks location on the cut-slope and tunnel portal area(a), and cracks on tunnel portal(b)



(a) (b)

Figure 3. Cracks monitoring result (#2, 4, 7, 9)(a), and cracks linkage(b)

3. Numerical Analysis Condition

This study performed numerical analysis using the FLAC program to check the displacements and their pattern of tunnel portal area including cut-slope. In case of 00 tunnel, steel pipe supports of one row were reinforced after excavation, and deformation of shortcrete and cracks were observed at sidewall of tunnel portal. In addition, cracks have been developing on the surface of cut-slope adjacent/above to tunnel portal. This numerical analysis selected STA.7+110 point as an interested section because that area seems to be mostly afffected by uneven pressure. As for the jointed rock mass properties input, rock mass properties derived by GSI system (Hoek and Brown, 1997) and ubiquitous joint model were applied. Detailed analysis condition is as shown in Table 1. Analysis model and principal discontinuity applied by ubiquitous joint model is as follows:

Table 1. Numerical Analysis Conditions

Name	Section	Reinforcement		Excavation	Load allocation
00 tunnel	Sta. 7+110	Steel pipe support of 1 row	Type Ⅵ	Upper half	40-30-30

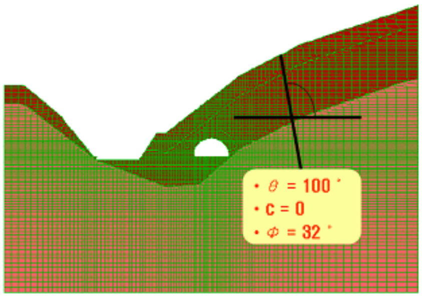


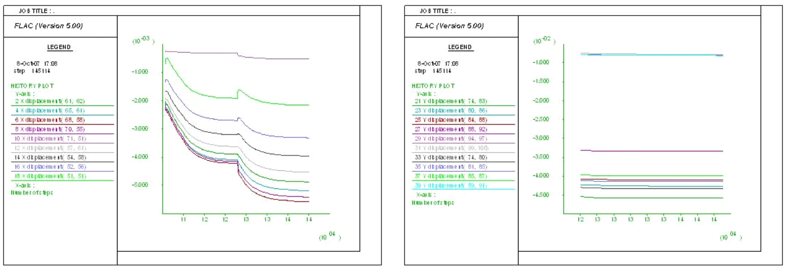
Figure 4. Numerical analysis model and principal discontinuity (schistosity)

4. Numerical Analysis Results

Fig. 5 shows horizontal displacements around tunnel portal when mixing ubiquitous joint model into jointed rock mass propertied derived by the GSI systems. As shown in Fig. 5 (a), maximum displacement value was about 5.1 mm, which is consistent with real monitoring results lie between 5~6 mm. It can be presumed that since ubiquitous joint model affects cohesion mostly among rock mass properties, mixing ubiquitous joint model with the GSI system which tends to overestimate cohesion could bring most similar result with field situation. Based on this assumption, detailed evaluation on numerical analysis was proceeded. Fig. 5 (b) shows displacement results on the surface of cut-slope above tunnel portal area. Their maximum displacement value was about 4.5 cm, which is similar with monitoring results of cut-slope (Fig. 3, (a)). Furthermore, this study compared displacement vectors with another numerical analysis result which applied minimum input value among literatures, empirical equations, and field test results. Fig. 6 shows displacement vectors, separately. As shown in Fig. 6(a), both cut-slope and tunnel area was totally collapsed when applying minimum input value. On the contrary, in this analysis condition, overall pattern that large displacements was generated on the surface of cut-slope above tunnel portal as well as displacements at sidewall of tunnel portal were developed along with direction of uneven pressure was well matched with real construction site's situation. Therefore, it is verifiable that uneven pressure played a critical role in developing left-downward displacement vectors and stress.

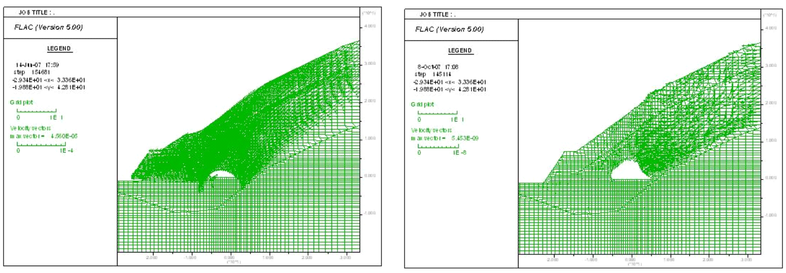
5. Conclusion

When performing numerical analysis on tunnel portal area subjected to the uneven pressure, it is important to simulate analysis conditions consistent with site situations to draw reliable results. However, most geotechnical programs are based on the elasto-plastic Mohr-Coulomb model, which accomplishes continuum model analysis in spite of jointed rock mass condition. To apply jointed rock mass into continuum model analysis, reduction of rock mass strength is required, and this study tried to apply rock mass properties derived by the GSI systems into numerical analysis. In addition, the ubiquitous joint model was introduced to jointed rock mass properties derived by the GSI systems for more elaborate simulation of field situation. As a result, when mixing ubiquitous joint model with jointed rock mass properties based on GSI system, reliable displacements and their pattern were derived. It is attributable to the point that ubiquitous joint model makes up for overestimated cohesion value derived by the GSI system which is one of techniques of reduction, and inserting schistosity as a main discontinuous plane induces similar stress pattern with real field situation. Method mixing GSI system with ubiquitous joint model drew the most reliable displacement and vector pattern, therefore numerical analysis based on the GSI system + ubiquitous joint model proposed by this study would be utilized effectively to design and check stability of joint rock slope/shallow depth tunnel.



(a) (b)

Figure 5. Numerical analysis results(displacement) near tunnel portal(a), and on the cut-slope surface(b)



(a) (b)

Figure 6. Displacement vectors from minimum input value(a), and this simulation(b)

Reference

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