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Field investigation and numerical analysis of landslide induced by tunneling

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ABSTRACT

The landslide induced by tunneling is very complex, since it may be influenced by not only geological condition, designed tunnel structure, construction environment or method, but also construction deficiency without in-time treatment. In this paper, a case of landslide induced by excavating a large-span multi-arch tunnel is studied by field investigation, in terms of tunnel profile, construction deficiencies, stability of surrounding rocks and landslide situation. Moreover, the landslide induced by tunneling is simulated based on the field investigation, even taking account of the observed construction deficiencies in the transverse section of tunnel within the area appeared landslide, resulted from tunneling without in-time treatment. Especially, a fictitious material is proposed for modeling the construction deficiency of cavity arisen from over-breaking of surrounding rocks without in-time backfilling, assumed as lightweight and always elastic without cracking, linked with primary lining and surrounding rocks using elastic spring. The numerical result is similar with that observed from field situation.

1. Introduction

Many studies on landslide induced by tunneling or mining have been presented in terms of geological-condition investigation [1–3], model test [4], numerical analysis [5–8] and theoretical analysis [9]. The landslide induced by tunneling is very complex, since it may be influenced by not only geological condition, designed tunnel structure, construction environment or method, but also other influencing factors, such as construction deficiency without in-time treatment, resulted from bad construction quality.

In this paper, a case of landslide induced by excavating a large-span multi-arch tunnel is studied by field investigation, which should be sufficiently strengthened in common [10]. The landslide induced by tunneling is also simulated based on the field investigation, even taking account of the observed construction deficiencies in the transverse section of tunnel within the area appeared landslide, resulted from tunneling without in-time treatment. Especially, a fictitious material is proposed for modeling the construction deficiency of cavity arisen from over-breaking of surrounding rocks without in-time backfilling.

2. Profile of the large-span multi-arch tunnel

2.1. Landform and geological condition around tunnel site

Fig. 1 shows the geological condition of the large-span multi-arch tunnel with total longitudinal length of 220 m, which was buried with shallow depth and asymmetrical pressure. The multi-arch tunnel was located in a lower hillside with steep

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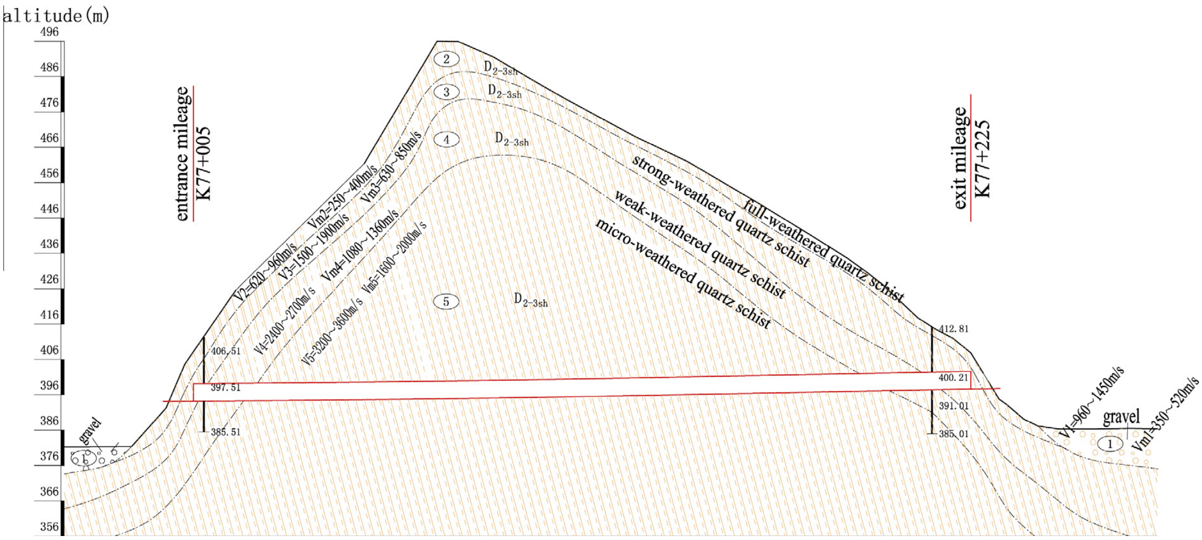

Fig. 1. Geological condition of the multi-arch tunnel.

Fig. 2. Site scene at tunnel entrance before landslide.

slope ranged from 45° to 60° due to the limited route line of the highway, and axial line of the multi-arch tunnel was perpendicular to the ridge alignment of the lower hillside. The major rock strata in tunnel body were crushed and embedded configuration of rock blocks, constituted of weakly-weathered and micro-weathered quartz schist with flat and middle-developed joint fissures, which were a little opened or closed.

However, the major rock strata at tunnel entrance and exit were crushed and loose configuration of rock blocks, constituted of fully-weathered or strongly-weathered quartz schist with very-developed joint fissures, which were a little opened and filled with mud. Especially, the bedrocks of tunnel entrance and exit were uncovered directly, as shown in Fig. 2. Therefore, the surrounding rocks of the multi-arch tunnel were very unstable, which might cause tunnel collapse.

2.2. Construction procedures

Fig. 3 demonstrates the construction sequences for constructing the multi-arch tunnel, named as three-pilot drift heading method, in which middle drift and twin-side drifts were excavated prior to excavating the main tunnels, in order to reduce the disturbance of unstable surrounding rock. In Fig. 3, the numbers of 1–24 represent the construction steps, and the red arc lines denote the temporary primary linings in the three-pilot drifts, required to be removed while excavating the main tunnels.

As shown in Fig. 3, the middle drift was constructed firstly: step 1 and 2: excavate upper and lower benches of middle drift → step 3: support primary lining of middle drift → step 4: cast vertical middle wall.

Thereafter, the twin-side drifts was constructed by following sequences: step 5 and 6: excavate upper bench and support primary lining of outer main tunnel's drift → step 7 and 8: excavate lower bench and support primary lining of outer main tunnel's drift → step 9 and 10: excavate upper bench and support primary lining of inner main tunnel's drift → step 11and 12: excavate lower bench and support primary lining of inner main tunnel's drift.