Tunneling in the Fragile Ground with Low Competence Factor Affected by Faults

— Nakaoyama Tunnel —

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1. Introduction

The Nakaoyama Tunnel is a 1,428-meters road tunnel of the Minami-Kyushu Expressway. Mt. Nakao has a geological structure composed of pyroclastic strata covered with andesite. As the competence factor is low due to a large overburden (maximum overburden: 250 m) on a soft ground, a massive plastic deformation has occurred. This report describes the measures to prevent displacement during tunneling work.

2. Occurred Phenomenon

Tunneling work was advanced while checking the ground conditions by conducting survey boring ahead of the face. However, due to a change in the geological features from around 250m point of the tunnel, pumice tuff and tuff accompanied by a fault, which is not assumed in the preliminary geological survey, appeared on the tunnel cross section (Photo 1).

As the displacement increased with the presence of these strata, breakage of rock bolts and cracks on the shotcrete became prominent. While the displacement proceeded even after the face separation exceeded 3D (D: tunnel diameter), the final displacement amount in the horizontal direction was over 180 mm.

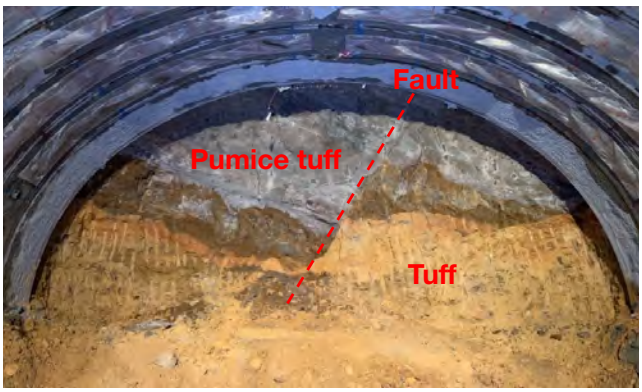

Photo 1 Occurrence of fault

Support pattern	Overburden (m)	Deformation margin (mm)	Shotcrete		Steel arch support work		Rock bolt		
			Strength (N/mm^2)	Shot thickness (cm)	Type	Installation interval (m)	Length (m)	Circumferential direction (m)	Extension direction (m)
DⅡ	56～112	100	18	20	NH-150	1.0	4.0	1.2	1.0
DⅡ-H1	112～200	100	18	20	HH-154	1.0	4.0	1.2	1.0
DⅡ-H2	200以上	100	36	20	HH-154	1.0	4.0	1.2	1.0

Table 1 Support pattern

3. Measures to Prevent Displacement

The original design for this tunnel set a three-stage pattern combining the steel support work and shotcrete (Table 1), however, the deformation of support and the increase in inner space displacement was not avoidable even with the highest-level pattern (DII-H2).

As a countermeasure, we provided early closure to establish a ring structure through early work (within 1D from face separation) with the invert strut and shotcrete (Figure 1). As a result, the status immediately inclined to convergence. Regarding the stress on support members, it was confirmed that compressive stress was applied to the entire ring and that the sufficient margin was secured for the yield of members.

After that, tunneling work was advanced while controlling displacement by early closure; however, the initial inner space displacement before the early closure increased due to the increased overburden (lowering of competence factor). We determined that the reason of this increase in displacement was lack of support pressure against the stress from the ground. Accordingly, we increased the member thickness by upgrading the support and improved the support pressure to restrain the inner space displacement until the cross-section closure. We adopted easily available common steel (NH200) for steel support work and shifted to the support pattern with increased support pressure by changing the shotcrete thickness from 200 mm to 250 mm. As a result, we successfully restrained the initial displacement and suppressed the increase of construction costs while ensuring stable construction at the same time.

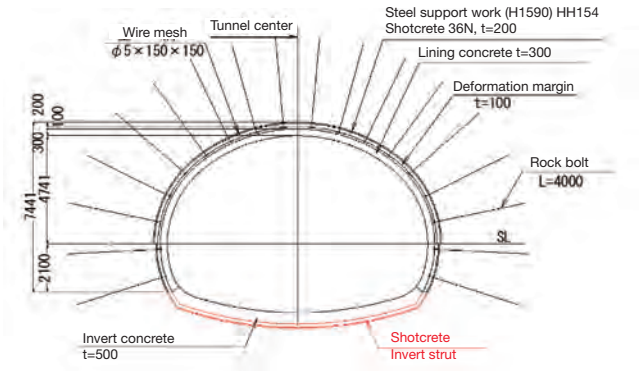

Fig. 1 Support pattern drawing