Heaving of roadbed Countermeasures in Squeezing Ground

– The Case of Tawarazaka Tunnel on the Kyushu Shinkansen (West Kyushu) –

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In mountain tunnels, there are cases in which heaving of roadbed occurs in the invert after the tunnel is completed, necessitating appropriate countermeasures. After the tunnel is put into operation, however, construction measures to deal with heaving of roadbed become difficult and pose a significant burden from an economic perspective. Yet, currently it is difficult to predict the occurrence of heaving of roadbed at the time of excavation and to select appropriate countermeasures.

1. Construction conditions of the Tawarazaka Tunnel

The Tawarazaka Tunnel on the Kyushu Shinkansen Line was built using the mountain tunneling method as a double track railway tunnel. The geology consists mainly of Paleogenic mudstone intercalated with tuff. The strength of the mudstone is approximately 10 MPa, and there are numerous latent cracks. The results of the rock slaking test exceeded the index that suggests high probability for occurrence of heaving of roadbed. Expansion of the internal space convergence that accompanies the increase in ground plasticity, and negative convergence trends were also confirmed. These symptoms prompted the implementation of early closure using a primary invert with the objective of limiting the convergence and achieving stability for the tunnel and the surrounding ground. In the locations where the convergence was particularly large, highly rigid supports were installed in order to restrain convergence during construction (Fig. 1).

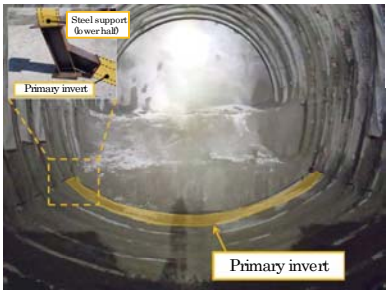

Fig. 1 Construction of primary inverts

2. Examination based on numerical analysis

The convergence in the section, in which early closure was implemented with primary inverts, was evaluated from start to completion of construction using a systematic evaluation method. The analytical model was 60 m in the vertical direction, 40 m in the transverse direction, and the total length of the tunnel was 90 m. Excavation was represented using methods for three-dimensional successive excavation, and the model assumed that the heaving of roadbed after completion of the tunnel will involve decline in the shear strength in line with the fracture proximity (loosening) of the ground (Fig. 2). Based on the excavation data, the author implemented reproducible analysis of the tunnel excavation and made a prognosis about the deformation of the tunnel ten years after completion. The results indicated that the convergence after completion was 3.6 mm during the ten years after completion,

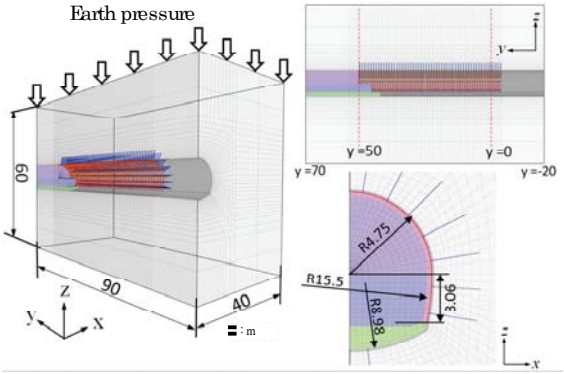

Fig. 2 Analysis model diagrams

and the heaving of roadbed was 1 mm for the same period. These results indicated that it is possible to restrict convergence to an extremely low level (Fig. 3).

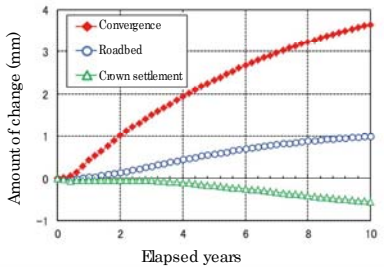

Fig. 3 Relation between convergence and the number of years passed after completion

3. Construction and measurement results

In the section where primary inverts were constructed, measuring devices were installed in the concrete of primary invert to measure the stress, which has an impact over the long term (Fig. 4). Shotcrete is affected by stress immediately after excavation, but stress was maintained below the values for design strength (18 N/mm^2), and it is believed that the placed shotcrete continues working as a support component of sufficient resistance. It was confirmed that although stress affects invert concrete and lining concrete, overall this stress was low.

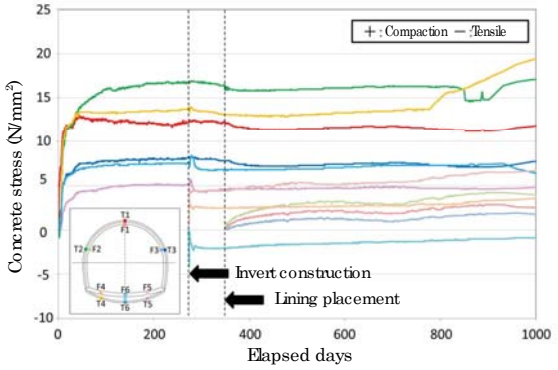

Fig. 4 Long-term measurement of concrete stress