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Verification of Deformation During Excavation of Pelitic Schist and Effect of Countermeasures

— The Matsukaya Tunnel on National Highway Route 197 —

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Introduction

The Matsukaya Tunnel is a two-lane road tunnel with a total length of 1,090meters. The soil consists mainly of fragile pelitic schist. During the excavation, maximum horizontal displacement of 770mm in one side occurred, along with significant deformation of the primary support including cracks in shotcrete, fractures of rock bolts and buckling of steel support, in addition to cracks and heaving of invert concrete.

This paper describes the construction results in fragile pelitic schist and countermeasures against the risk of deformation developed in the tunnels in service. It also reports the verification results through numerical analysis of the mechanism of deformation and the effectiveness of countermeasures.

1. Excavation Situation

During the excavation of pelitic schist, damage and extrusion of the primary support occurred frequently (Photo 1).
To secure the soundness of the primary support and the necessary inner space, the primary support had to be repeatedly rebuilt. After the excavation, the invert was closed early to control the displacement and stabilize the tunnel. However, the earth pressure increased with time even after the invert was closed, and the steel support buckled (Photo 2). In addition, damage and heaving of the invert concrete were recognized, and tunnel was considered at risk of deformation after the start of service.

Photo 1 Extrusion of primary support

Photo 2 Buckling of steel support

2. Countermeasures Against Deformation

To stabilize the tunnel during construction, the thickness of shotcrete was upgraded from 15cm to 20cm, and the steel support from H-125 to H-150.
To cope with the risk of tunnel deformation after the start of service, the invert was reinforced with invert struts as shown in Figure 1, and non-steel fiber was mixed in the lining concrete to prevent flaking.
In addition, for the purpose of confirming stability of tunnel in service and detecting signs of deformation early, stress measurement and convergence measurement of lining and invert concrete were planned, and they were carried out from the start of construction.

3. Verification Through Analysis

To simulate the phenomenon at the time of excavation and to verify the effect of countermeasures, numerical analysis with the following features was carried out.

- From the linear elastic analysis of the wide area model, the initial stress state of the tunnel's surrounding bedrock is obtained (Figure 2).

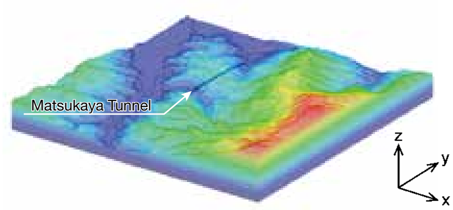

Fig. 2 Wide area terrain model

- The degradation model was based on the Mohr-Coulomb yield criterion, and the strength decreased with time after plasticity.

As a result, the following phenomenon were simulated: (1) at the time of excavation, large displacement occurred in the mode in which horizontal displacement was dominant, (2) primary support was damaged again after invert closure, and (3) invert was heaved. In addition, this model proved that the future stability of the tunnel is ensured even if the ground strength was further reduced, confirming the effectiveness of the countermeasures (Figure 3).

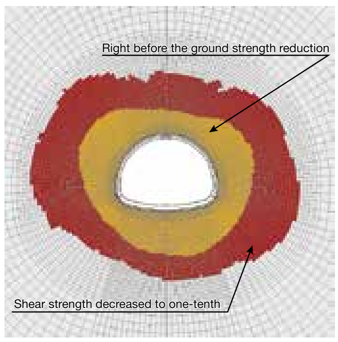

Fig. 3 Change in plastic zone due to bedrock degradation

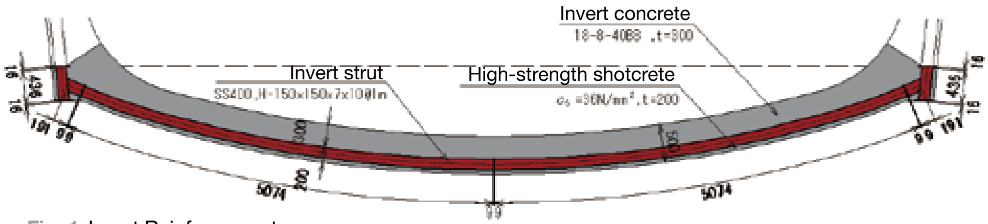

Fig. 1 Invert Reinforcement