Excavation of Phase II Tunnel by Early Cross-Sectional Closure at Distance of 0.85m from In-Service Tunnel

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Introduction

Kisaichi Maruyama Tunnel, an expressway tunnel, started the service in 1993 with temporary two-lane traffic. In 2019, the Phase II tunnel for 4-lane expansion will be constructed over the 125m of entire line very close to the Phase I tunnel in service at a distance of 0.85m. Furthermore, the overburden of the tunnel is less than 1.5 times the width of the excavation, and Kisaichi Maruyama Burial Mound, a national historic site, is located near the ground surface. (Photo 1, Fig.1, Fig.2)

Photo 1 Kisaichi Maruyama Tunnel

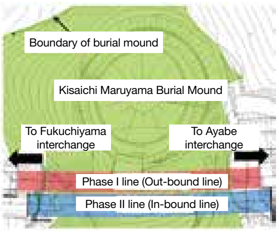

Fig. 1 Plan drawing of Kisaichi Maruyama Tunnel

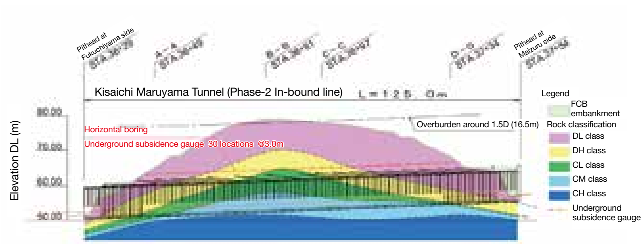

Fig. 2 Geological Profile

1. Construction method

For the Phase II tunnel, we early closed the tunnel with 8m of closing distance by using full-section excavation with an auxiliary bench in order to suppress the deformation. We selected the support of DIII pattern for the entire line (Fig. 3). We applied all ground fastening method along the entire line to prevent collapse. The steel pipe was ϕ 114.3mm, t=6mm, L=12.5m, and the setting range was 120°. A double arrangement with a shift length of 5m was used at the entrance, and a single arrangement with a shift length of 9m was used at the central part of the tunnel.

For the gap of 0.8m between Phase I and Phase II tunnels, injection type fore polling was placed in and improved with urethane-based injection material to prevent collapse during excavation (Fig. 3).

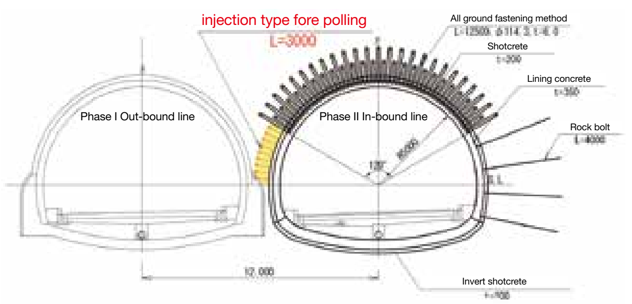

Fig. 3 Support pattern for Phase II line

2. Measurement control

We installed horizontal inclinometers in the horizontal boreholes at the top of Phase II line at 3m intervals to measure the amount of subsidence at the top in real time before passing through the face. (Fig.4)

We set the control standard value for the subsidence as 30 mm, which is obtained by FEM analysis when the increased tensile stress of the Phase I line reaches the allowable value (1,080kN/m^2, which is 6% of the design standard strength). In addition, we created a characteristic curve of the control standard value according to the distance from the measurement point to the face in order to predict the final displacement of the measurement point before it converged. Based on the data we took early countermeasures according to each control level. The shape of the characteristic curve was calculated by three-dimensional FEM analysis. We set the curve so that subsidence starts at the location of 30m in front of the face, converges to 17mm when passing the face, and converges to a final settlement of 30mm after the face passed 30m.

3. Construction result

Although the ground subsidence started at a location closer to the face than predicted, the final subsidence amount was almost consistent with the predicted analysis value. Since the subsidence amount before convergence was also below the control level of the characteristic curve, additional countermeasure or traffic restrictions of Phase I tunnel was not required. (Fig. 4).

The method of early closure by full-section excavation using all ground fastening successfully suppressed the displacement of the tunnel and reduced the impact on the Phase I tunnel to ensure the soundness of the tunnel. We concluded that our approach was an appropriate construction method for the adjacent construction of tunnels in service.

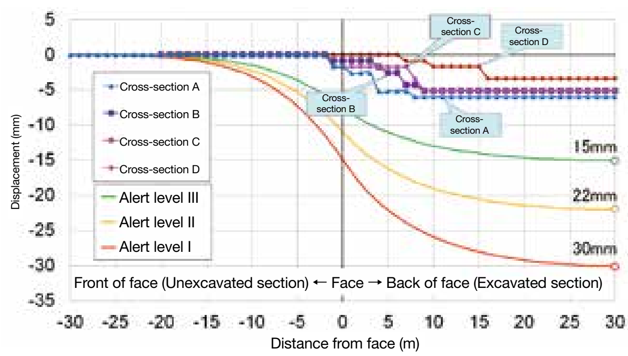

Fig. 4 Result of Ground Subsidence