First Ever Tunnel Invert Reinforcement on a Highway Using Timbering Support Method

Masayuki SHIMIZU ▶ Section Manager, Nagaoka Management Office,
East Nippon Expressway Company Limited

Outline

The outbound line of the Yoneyama Tunnel of the Hokuriku Expressway is a 1,616m long tunnel constructed using the timbering support method, and has been in service for about 40 years since 1983. It is mainly composed of Neogene mudstone and sandstone-mudstone alternation layers, and according to the results of X-ray diffraction analysis, it contains trace to small amounts of smectite, a swelling clay mineral. The pavement surface rose by a maximum of 108 mm in 1996, and the Chuetsu-oki Earthquake in 2007 caused damage such as partial peeling off of the lining surface. Since the road surface is still rising, renewal work was conducted to install new inverts in 2022. This work lasted for a total length of L=450m at locations where: seismic effects by the Chuetsu-oki Earthquake and other reasons existed, and where road surface displacement was 20 mm or more and displacement speed was generally 0.5 (mm/year) or more. Since the inverts were to be constructed on an expressway that was still in service, the plan was to construct the entire width of the invert in one piece, while closing off the outbound line and switching the outbound traffic to the inbound line for two-way traffic.

1. Planning the Reinforcement of Inverts

Tunnels constructed using the timbering support method are reverse-wound, with the upper half concrete of one 12-meter span of lining constructed first, and then the sidewall concrete is placed. This results in having joints on the upper half and sidewalls, and if the lining footings were excavated at one time, there is a possibility of having deformities such as lining settlement and cracks in the joints. The length of the invert excavation was compared using numerical analysis, and was decided at the half of the 12 m span of the lining, L=6 m.

As a preliminary work for the invert installation, reinforcing bolts were cast prior to the countermeasures. The purpose of the sidewall reinforcement bolts was to suppress the settlement of the lining and deformation of the sidewalls during the invert excavation. A total of 1,812 bolts were cast in the L=450 m length of the invert countermeasure, three on each side of each section, L=4 m, with a casting interval of 0.9 m pitch in the vertical direction and 1.5 m pitch in the tunnel axis direction (Figure-1).

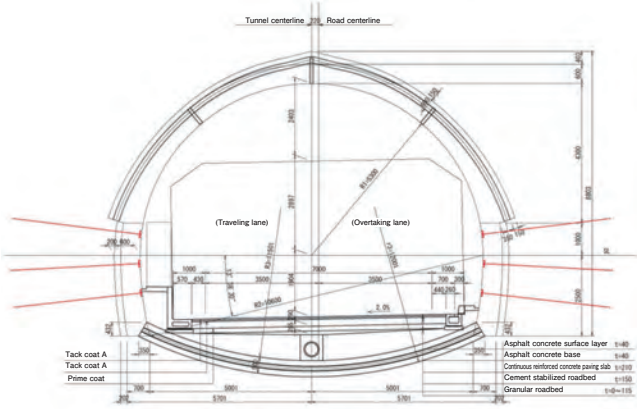

Fig. 1 Cross-section of reinforcement bolt

2. Steps in Invert Excavation

For the invert excavation, the L=6m block was constructed in advance of all odd-numbered spans, as shown in Figure-2, and all even-numbered spans were constructed in the back row. The construction of the initial excavation of the first excavation span was carried out with enhanced monitoring and meticulous care. The sequence of each construction was as follows: (1) excavation of the center, (2) excavation of the overtaking side earth level, (3) excavation of the traveling side earth level, support installation, formwork installation, and pouring of invert concrete, while confirming validity based on the measurement results together with the construction status (Photo-1).

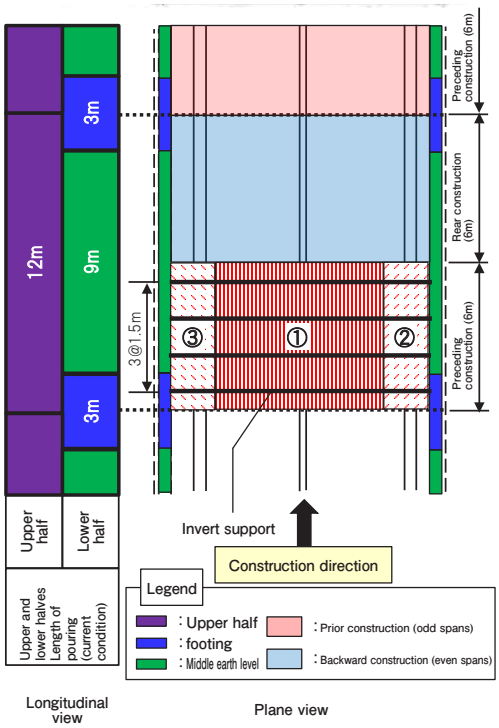

Fig. 2 Excavation layout

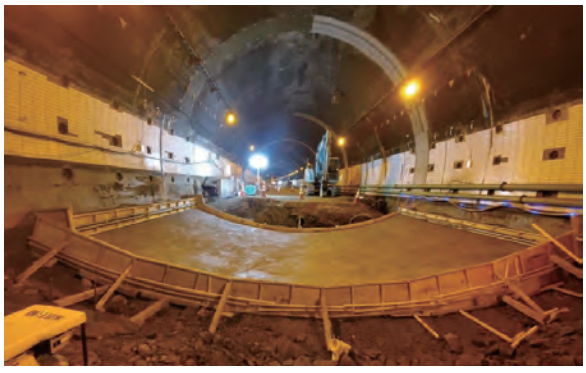

Photo 1 After placing invert concrete