Tunnel drilling in weak ground using the Early Cross Section Closure Method

– Chubu Odan Expressway, Hachinoshiri Tunnel –

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1. Project overview

The Hachinoshiri Tunnel is a mountain tunnel on the Chubu Odan Expressway, an expressway that crosses Honshu. It is located at the foot of Mount Fuji, approximately 100 km west of Tokyo. The tunnel has a total length of 2,469 m and excavation face of 82 km^2. The excavation method was full-face NATM using a large-scale tunneling machine (Road Header 330 kw [Photo 1]), and a belt conveyer system was used for mucking. The tunnel was excavated between August 2011 and August 2015, and was opened for traffic in March 2017.

Photo 1 Tunnel excavation

2. Geological conditions

The geology of the project site was composed of a gravel layer, landslide colluvial soil, mudstone, basaltic lava, and basaltic pyroclastic rock. Landslide morphology was confirmed in the vicinity of the starting shaft (the shaft in the northern end), and it was also projected that construction would encounter weak mudstone ground with uniaxial compressive strength of around 0.1 N/mm^2 (competence factor qu/γH<0.1) in the central area of the tunnel. Also, there were concerns over possible deformation, breakdown or excessive displacement of support materials in construction work using standard support patterns for 22% of the full length of the tunnel. Overall, the geological conditions made ensuring tunnel stability a difficult task (Fig. 1).

3. Tunnel stabilization methods

Below is a list of the construction technologies adopted as tunnel stabilization measures in weak ground for this tunnel construction project.

▷ Long span steel pipe forepiling as a measure to reinforce the face crown, as well as long-span face bolts and curved face as a measure to stabilize the face (a method to improve the autonomy of the face with arches by excavating in a spherical shape)

▷ Full face Early Cross Section Closure Method adopted in order to interrupt any convergence at an early stage (invert closure at 3-6 m behind the face)

▷ Improving the strength of supports ⇒ Installation of steel arch supports H-200, high-strength shotcrete t=300 (design strength 36 N/mm^2), high strength rock bolts L=4 m (pulling resistance 170 kN)

▷ Three-dimensional measurement control using 3D scanners with the objective of appropriately assessing face shape and improving the efficiency of the three-dimensional behavior monitoring

4. Occurrence of deformation during construction and countermeasures

During construction in the area composed of weak mudstone, the project encountered unexpected squeezing-type ground pressure equivalent to approximately 2 MP, leading to the occurrence of convergence of up to 675 mm. To deal with this issue, the following measures were implemented in order to ensure durability of supports, and eventually structural soundness of the tunnel was restored by re-excavating the tunnel and re-building the supports in a 125 m-long section.

▷ Significant improvement of the support strength through installation of double-tier supports (steel arch supports: primary H-250 + secondary H-200, shotcrete primary t=300, secondary t=200) 【Fig. 2】

▷ Upgrading rock bolts to ultra-high strength bolts (pulling resistance 290 kN)

▷ Adding steel supports to the invert sections, and reducing the size of curvature to the same extent as the arch sections and making the shape of the tunnel as close as possible to a circle in order to suppress the occurrence of a bending moment.

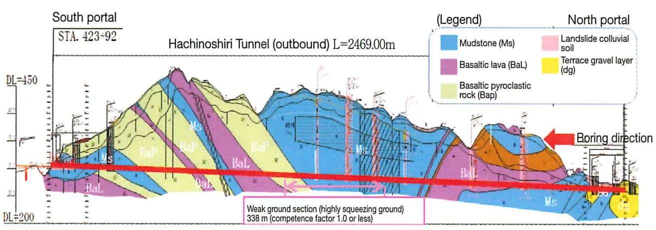

Fig. 1 Geological profile

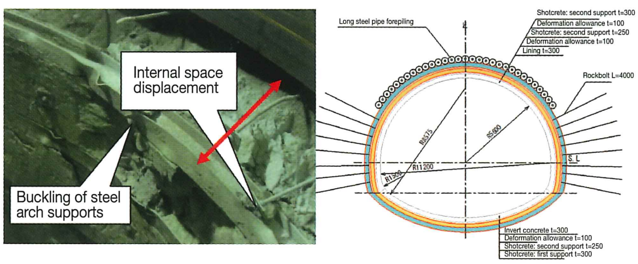

Fig. 2 Tunnel profile (double-tier supports)