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22.5% uphill electric cable tunnel by mud-pressure shield in composite ground containing weathered granite

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1. Geological overview and investigation

The geology was a very compact sand and gravel layer mixed with cobble stones with a maximum diameter of 3,000 mm up to about 400 m from the start of the tunnel. After that, the granite at 1,100 m was weathered to qu=1MN/m^2 at depths shallower than 20 m. The distribution of faults, etc., was also examined. The distribution of faults was determined using a reflection survey.

2. Cross-section and alignment

The inner diameter of the power cable tunnel was 3,000 mm. The longitudinal alignment was designed to have an approximate elevation difference of 120 m between the start and arrival points, with a gentle slope of less than 5% for 1,100 m, a horizontal section of 50 m, and a steep slope of 22.5% for 350 m (Figure 1). In Japan, there have been only a few shield tunneling projects with a steep slope exceeding 20% for more than 350 m in a row (about 4,300 projects), making this a rare case.

3. Challenges and countermeasures for composite ground

A mud pressure shield was used to tunnel a single shield through composite ground where sediment and bedrock were distributed. A faceplate-type cutter head and roller cutter were equipped to crush the bedrock to less than 300 mm in size and remove boulders (max. Φ 300 mm) from the sand and soil. In addition, a roller cutter was installed in the center of the cutter to cope with the unexpected appearance of hard rock in the bedrock area.

4. Shield equipment for constructing a steep slope of 22.5%

The segments were made of RC segments with smooth inner surfaces. A water-assisted earth moving system was used to discharge the earth from the tunnel (Figure-2). Although a mud treatment plant was required, the majority of the soil was disposed of as general overburden, thus reducing the environmental impact. In order to construct the steep slope of 22.5%, a rack-and-pinion battery car, a runaway prevention device, an automatic horizontal segment cart, and an electric segment feeding device were used.

5. Construction results

During excavation of earth and sand, problems such as blockage of the soil drainage pipe occurred due to the appearance of boulders with a maximum diameter of 400 mm, which was larger than expected, but the excavation did not stop for a long period of time and was generally stable. During the excavation of bedrock on a gentle slope, the thrust tended to be high, but this was overcome by increasing the injection rate of an additive material (polymeric coagulant). In the steep-gradient section, granite that had been subjected to strong winds formed gravels, which lodged in the pump empennage and interfered with pump rotation. The pumps were able to reach the same speed (average 153 m/month) in the steep section as in the other sections, and the overall process took about 10 months (average 143 m/month) for a distance of 1.5 km, as originally planned (Photo-1).

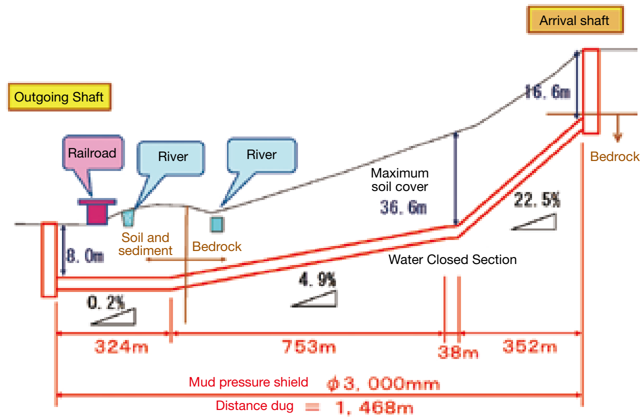

Fig. 1 Shield longitudinal alignment

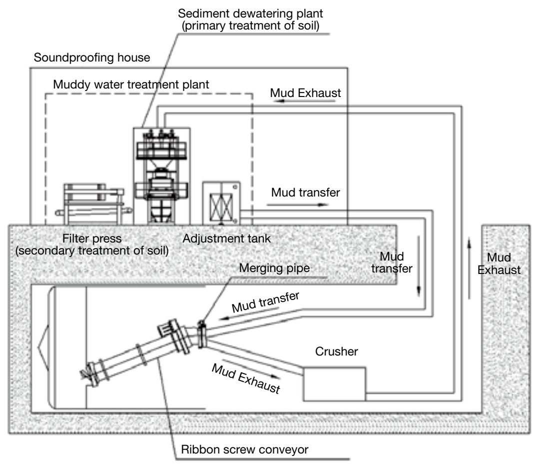

Fig. 2 Image of water-assisted earth moving system

Photo 1 Arrival status