Excavation directly under the main road in an urban area using the mountain tunnelling method with pipe roofing

— Kyushu Shinkansen West Kyushu Route, Isahaya Tunnel —

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Introduction

The Kyushu Shinkansen (West Kyushu Route) is a high-speed rail line connecting Fukuoka and Nagasaki prefectures in Kyushu, Japan. An extension of 67 km between Takeo Onsen and Nagasaki is currently under construction and scheduled for completion in fall of 2022. The Isahaya Tunnel is a 230-meter-long tunnel that passes through a busy national highway with a small soil cover of about 3.5 meters. The ground is mainly composed of a tuff breccia layer containing hard gravel (Fig. 1 and 2). In order to minimize the impact of the tunnel excavation on the road traffic, the tunnel was excavated by the mountain tunneling method using pipe roofing to prevent the road surface from sinking. This paper introduces the features of pipe roofing in this tunnel.

Fig. 1 Isahaya Tunnel plane figure

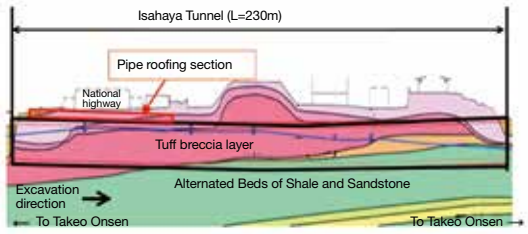

Fig. 2 Isahaya Tunnel longitudinal view

1. Construction plan for national highway intersection

The national highway section has a traffic volume of 25,000 vehicles per day, as well as many buried pipes for water, sewage, electricity, communication, and gas. In order to avoid the social impact of traffic restrictions on the main road and the replacement of various buried pipes, the mountain tunneling method was applied to this tunnel.

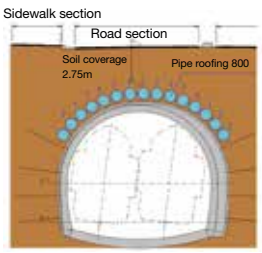

Fig. 3 Cross-section figure of the Isahaya Tunnel's national road area

The pipe roof method (Φ 800mm, L=60m x 15 pipes) was adopted as a countermeasure to prevent the road surface from sinking and to preserve the function of the buried pipes (Fig. 3).

2. Features of pipe roofing used in this tunnel

When the pipe roofing method is applied to tunnels with small soil cover, there is concern about water inflow through the gaps between adjacent pipe roofs (steel pipes) and into the ground. In order to prevent this problem, the conventional method involves the installation of junctions between adjacent pipe roofs and excavating while joining them to eliminate the gaps between the pipe roofs. However, the ground to be excavated for this tunnel is composed of hard gravel (uniaxial compressive strength of 130 MPa or more, gravel content of 40-50%) with a diameter of 10 cm to 100 cm and soft substrate. Therefore, it was assumed that if the joint was disturbed by huge gravel, the joint would break, and excavation would become impossible.
Therefore, it was necessary to develop an alternative method to close the gap between the pipe roofs instead of using joints. In order to solve this problem, we devised the backfill lapping method, which consists of lapping the backfill instead of using joints. In this method, the distance between the pipes is set to 5 cm, and the backfill of the preceding pipe roof is cut by the following machine while excavating, and the backfill materials are lapped together to increase the tightness by filling the void between the pipes (Fig. 4).
The pipe roof construction requires high-precision excavation management, so a machine that can make real-time directional corrections within a range of ± 1.5° in the vertical and horizontal directions was used, and an ICT-based 3D propulsion accuracy management system was developed to achieve high-precision excavation management.

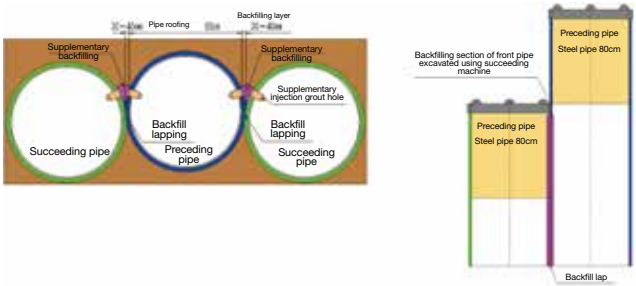

Fig. 4 Backfill lapping method overview

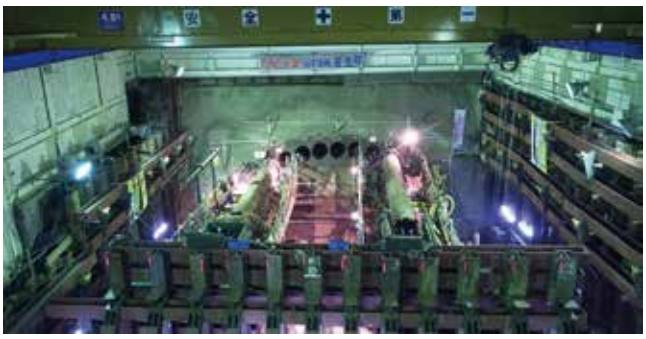

Photo 1 Pipe roofing scene