Overcoming mountain tunnels under strong ground pressure with a round triple support structure

— Otonaka Tunnel, National Route 40 Otoineppu Bypass —

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1. Overview

The Otonaka Tunnel (4,686m in length) on the Otoineppu Bypass of National Route 40 is a section of fragile serpentine rock, and was subjected to strong ground pressure rarely seen in tunnels, resulting in deformation near the cutting face and large-scale heaving and destruction of the arch tunnel support (Fig. 1). At the time of the deformation, a closed-ring support pattern with shotcrete t=45 cm and steel support H-200 was adopted, but the section where the deformation occurred was about 450m long, which meant that large-scale re-excavation was unavoidable. During the re-excavation of the deformed section, various surveys, measurements and numerical analyses were conducted to determine the support structure and construction method. A round triple support structure (Fig. 2) was adopted to ensure the stability of the tunne

Fig. 1 Buckling of the arch supports

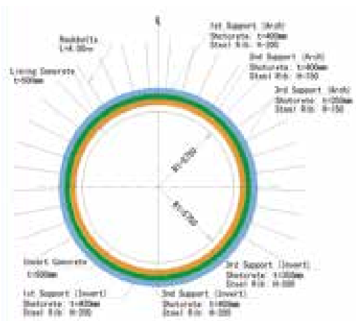

Fig. 2 Triple layered support pattern

2. Deformed section designs

Our view on the support structure of the re-excavation of the section with large-scale deformations is as follows.
The cross-sectional shape of the support structure is circular to ensure stability against strong ground pressure from all sides and unsymmetrical pressure under the heterogeneous ground. The required bearing capacity of the support structure was determined to be the maximum overburden of the serpentine section. The bearing capacity of the support structure was designed to ensure stability against the time-dependent increase in displacement and stress (back-loading) characteristic of serpentine. In order to construct the circular support structure as soon as possible, the cross-sectional closure of the support material was carried out as close as possible to the face. In order to shorten the release time of the face, the maximum thickness of the material that can be constructed at any given time was limited to 50cm.
The deformation modulus of serpentine was set to 150 MPa, the internal friction angle to 10° , and the cohesion to 60 kPa, based on the inverse analysis of the measurement data during the initial excavation and the ground sample test, and the required bearing capacity was determined by numerical analysis. In addition, the maximum incremental stress value assumed after 100 years was set as a time-dependent after-load by analyzing the measurement data during the initial excavation. As a result, a support pattern was designed to construct a round triple support structure (shotcrete 40 cm + 40 cm + 35 cm, steel support H-200 x 3) immediately after excavation (Fig. 2, Fig. 3).

Fig. 3 Ring closing near the tunnel face by triple layered Supports

3. Results of re-excavating the deformed section

Re-excavating the deformed section confirmed that the displacement of the upper half-horizontal inner space remained in the range of -60mm to -80mm and showed a gradual convergence trend after the section was closed. The estimated earth pressures acting on the support structure was slightly lower during the re-excavation than during the initial excavation, but generally increased with the overburden height during both the initial excavation and re-excavation, with the maximum earth pressure estimated to be equivalent to about 140m of overburden.

Triple Layered Tunnel Supports System against Extremely High Squeezing Ground Condition

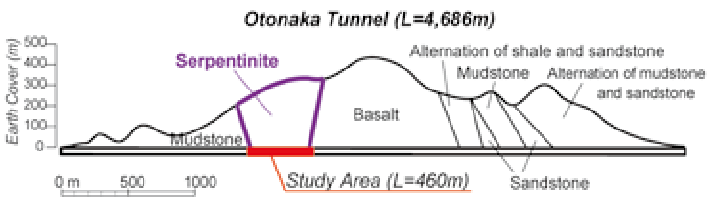

Fig. 1 Geological Profiles in the Otonaka Tunnel