Maintenance of the Railway Tunnel Built on Serpentinite

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The 4,523 m long double-track electrified section railway mountain tunnel, which is currently in service, was put into service on 1 October 1969, one year later than planned, due to numerous deformations such as support works being pushed out toward the inner space due to the squeezing of the ground since the initial excavation.
No significant deformations were observed during the first 18 years of service, but around 1987 the roadbed began to rise and the inner space to shrink in the horizontal direction, similar to that observed when the main tunnel was excavated. In 1996, measures were implemented at night when train operations ceased, since, from the start of measurements, the uplift of the roadbed in some sections was as large as 370 mm, and the inner space was also reduced by 73 mm below the sidewalls which were too large to ignore. Reinforcement work included ground anchors in the sidewalls as a countermeasure against the shrinkage of the inner space, and reconstruction of the joint between the invert and the sidewalls and of rock bolts in the roadbed (Fig. 1) to prevent the uplift of the roadbed, as the joint between the invert and the lower parts of the sidewalls had 'gaps' in its structure and could not transmit axial force.
As a result, the deformation was controlled.
After these measures, the gradual roadbed uplift and inner space reduction continued in other parts of the tunnel, and it was anticipated that if this deformation continued, more maintenance work would be required to keep the trains running safely. It was therefore decided to start countermeasure works again in 2010. The basic policy for the reinforcement work was, as the measures taken in 1996 were sufficiently effective, to use rock bolts to control the deformation in the same way. In addition, as 'gaps' were found at the joint between the invert and the lower parts of the sidewalls, the joint was reconstructed. Specifically, R32 self-drilled rock bolts (n=36) with a length of 9 m were driven in the center of the roadbed section in a downward direction, and R32 self-drilled rock bolts (n=33) with a length of 8 m were driven in the direction horizontal to the inbound line (Photo 1). To reconstruct the joint between the invert and the lower parts of the sidewalls, part of the lower parts of the sidewalls was demolished, reinforcing steel steel bars were jointed to the rebars of the invert and inserted into the sidewalls and fixed using chemical anchors, after which no-shrink mortar was cast (Photo 2).
To check the effectiveness of the countermeasures, the height of the roadbed surface was measured at standard intervals of 5 m in the direction of the railway line. While the maximum uplift rate before the countermeasures (from the start of measurement to the countermeasure implementation) was 13.4 mm/year, after the countermeasure (annual average uplift from the countermeasure implementation to August 2021) the maximum value was -0.1 mm/year, confirming that the situation has been improved (Fig1).

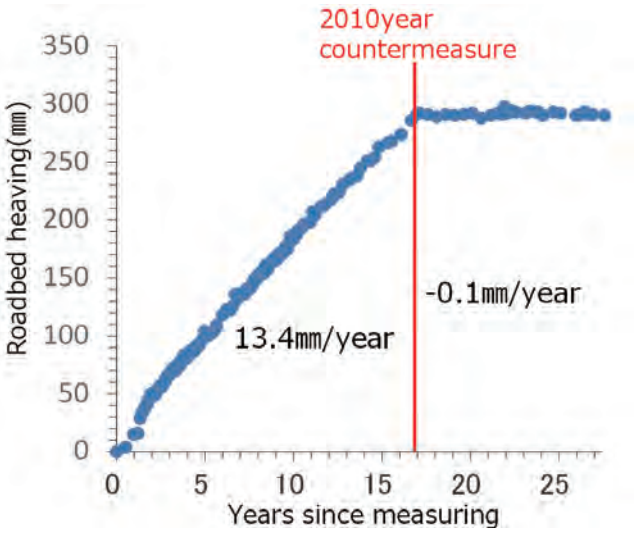

Fig. 1 Roadbed measurement

Photo 1 Self-drilled rock bolt placing

Photo 2 No-shrink mortar placing