Restoration after the Kumamoto Earthquake

— Tateno Tunnel of JR Hohi Main Line —

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1. Introduction

The Kumamoto Earthquake in April 2016 caused severe damage to the Tateno Tunnel of Hohi Main Line of Kyushu Railway Company, including cracks and spalling of the lining concrete inside the tunnel and rupture of the portal. The repair work for the large-scale slope failure caused by the earthquake affected the tunnel, and its full-scale restoration began in 2019, with the entire Hohi Main Line resuming operation in August 2020.
This paper reports the damage to the tunnel by the earthquake, presumed cause of the damage and the restoration method adopted.

2. Outline of the Tateno Tunnel

The Tateno Tunnel is a 218m-long, single-track, non-electrified tunnel completed in 1918. Its lining was constructed with cast-in-place concrete for the side walls and a mixture of brick and cast-in-place concrete for the arch and crown, a structure often seen in tunnels of the time.

3. Damage to the Tateno Tunnel

The foreshock of the Kumamoto Earthquake occurred at 9:26 p.m. on April 14, 2016, with the magnitude of 6.5 at the epicenter in Kumamoto region, and the main shock at 1:26 a.m. two days later, with the magnitude 7.3 at the epicenter. Significant deformation was observed in the following sections of the tunnel.
(1) Damage near the center of the tunnel
Cracks and spalling of the tunnel lining occurred due to seismic shaking. In particular, the lining was squeezed by approximately 70 mm to the inner side near the center of the tunnel (Photo-1).

Photo 1 Portal deformed conditions

(2) Portal rupture
The crown of the portal was ruptured by a vertical crack with an opening width of a few dozen millimeters, and bricks fell from the crown of the lining at the boundary. In addition, the sidewall of the lining, about 5 m from the portal, was squeezed 35 mm to the inner side of the tunnel (Photo-2).

Photo 2 Lining deformed conditions

4. Presumed cause of the damage and restoration method

Based on the survey boring and on-site inspection of the deformed section, the cause of the damage was presumed and operation was resumed in August 2020 after the following restoration work.

(1) The cause of the damage and restoration method near the center of the tunnel
Based on the results of boring survey, it was presumed that the damage was locally increased due to the different responses to seismic motion. This happened because the stratum boundary between andesite and tuff breccia, which have different relative strengths, were located in the damaged section. Restoration was performed with internal reinforcement but since the margin of the building limit was small, T3 panel method, in which steel supports and high-strength thin panels cover the inner lining, was adopted. (Photo-3). The thin panels, made of high-toughness cement board with aramid fibers structured in two directions attached, have a load capacity of 8 kN/ m^2 and the minimum construction thickness can be reduced to about 3 cm.
(2) The cause of the damage and restoration method at the portal
It was presumed that the ground displacement due to seismic motion was particularly large because the portal was located at the tip of a narrow ridge-like topography and the ground was relatively soft with a small overburden. The broken sections of the portal were repaired with reinforcing plates and rock bolts. The tunnel was integrated with the ground using grouting type forepiling (AGF method) and a 50-cm-thick face wall was constructed in front of the portal (Photo-4).

Photo 3 Inner reinforcing by T3 panel method

Photo 4 Portal restoration conditions