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Behavior of Segmental Linings During Construction of Super-adjacent Spacing Parallel Tunnels

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ABSTRACT : The affects on the construction of super-adjacent spacing twin tunnels using shield tunnel boring machine were considered on the design of segmental linings. For this design, the FEM analysis was used to evaluate the affects of the shield tunnelling method. Moreover, to clarify the behavior of the adjacent segmental lining during excavation of another side of tunnel, the precise monitoring of strain in the segmental linings were carried out. This paper discussed the results of the monitoring and evaluates the satisfaction of the design for segmental lining considering the comparison between the results of analysis and monitoring.

1. Introduction

Rinkai Line is a new railway of about 12.3km from Shinkiba Station of the JR Keiyou Line, by passing the Tokyo Bay redevelopment area and connected to JR Yamanote Line Oosaki Station. The first section from Shinkiba Station to Tokyo teleport Station was opened in March, 1996, and the second section from Tokyo teleport Station to Tennozu Aisle Station was opened in March, 2001. The construction of 4.4km from Tennozu Aisle Station to Oosaki Station is sped up now.

The work is construction by which a single track parallel tunnel of 7.1m in segment outside diameter is constructed with the slurry shield method using two numbers of shield tunnel boring machines about 983m from the Tennozu Aisle Station to the Shinagawa Seaside Station in the second construction section. The south bound line tunnel proceeded to dig the tunneling falling behind from the north bound line tunnel by about 150m.

The space between a parallel tunnel in the general part was about 2.8m, and partially to have constructed the no precedent super-adjacent spacing about 0.6m because the tunnel was constructed under the Tennozu street of width 18m by not seeing the example. Therefore, the site monitoring was carried out to observe the transformation of the segment of the super-adjacent part, and confirmed the safety of the segment.

In the paper, the influence which the super-adjacent parallel tunnel construction using shield tunnel boring machines exerts on the segment, it is a summary based on these monitoring results.

2. Monitoring of segment

This parallel shield passes 20m under the riverbed of the Tennozu south canal from the launching shaft at the position of about 820m. Higashi-Shinagawa bridge is laid in the Tennozu south canal, and these shield boring machines pass the position of the under about 3.0m of the bearing piles of the bridge in parallel with space 2.0m-0.6m the super-adjacent.

The method of designing such the super-adjacent parallel tunnel construction is not established so far, though the segmental lining in the part which passes under the Higashi-Shinagawa bridge is designed in it made of the ducktail cast iron in consideration of load of the bearing piles and the super-adjacent parallel tunneling influences. Then, the monitoring of the segmental lining was carried out to confirm the safety of the segmental lining design and the influence of the super-adjacent construction.

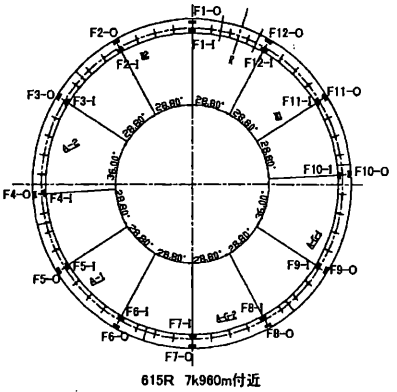


Figure-1 Gauge Arrangement

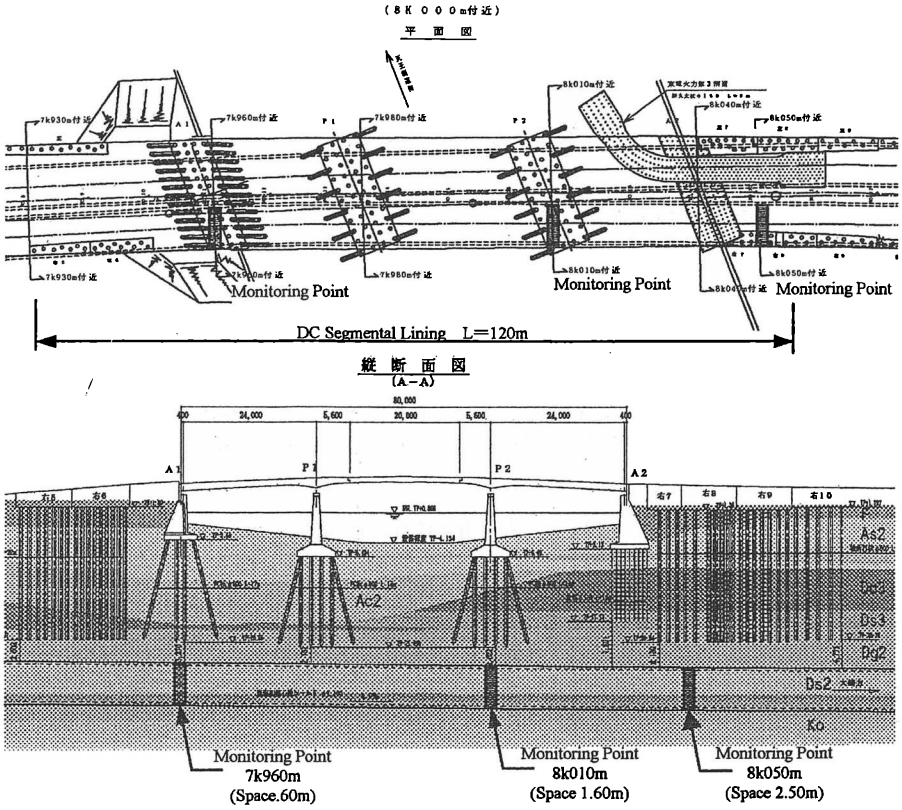


Figure-2 Monitoring Locations

2.1 Monitoring location and gauge arrangement

The ground condition in the location of segmental lining monitoring is roughly diluvium sand layer (Ds2) which N value of 40 or more, and mudstone layer (Kazusa layer Ko) appears lower portion of the tunnel section. Behavior on the segmental lining according to the south bound tunneling (post-line) was measured by installing the strain gage on the segment of the north bound tunnel (proceeding). Gauge position is shows in Figure-1 and the monitoring location is shown in Figure-2.

2.2 Setting of slurry water pressure

The construction place was under the Tennozu south canal, and earth coverings were lower than heads of the ground-water pressure at the tunnel position, and the blow of the slurry water to the riverbed was concerned. There is a possibility that Higashi-Shinagawa bridge subsides due to slurry water pressure shortage though it is necessary to set the slurry water pressure low to prevent the blow of the slurry water.

Therefore, at the position from the Tennozu south canal to this side about 250m where vertical load which acts on tunnel becomes almost the same under abutment of Higashi-Shinagawa bridge, excavation of shield machine was carried out to set the slurry water pressure in the value (0.29 Mpa) when the Tennozu south canal was passed, and the displacement of the ground was measured by the multi layers settlement gauges and the inclinometers. As a result of the measurement, small movement of the ground was appeared, the blow slurry water pressure was set to be a upper bound value for management of shield excavation in construction under the canal.

2.3 Analysis of influence to segmental lining

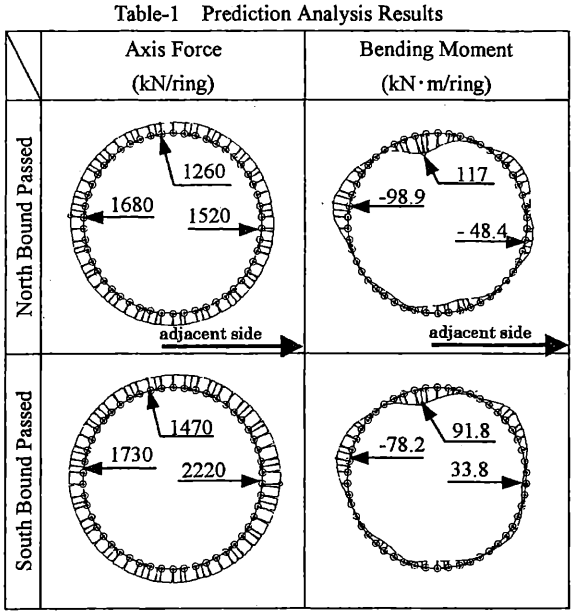
The prediction analysis of the behavior of segmental lining by the super-adjacent parallel tunneling was carried out on the ducktail cast iron segment under A1 abutment (Chainage 7k960m) of the Higashi-Shinagawa bridge.

The prediction analysis referred to an analytical technique of a parallel tunnel in "Design Standard and Explanation for Shield Tunneling Railway

Structures"(1997 Railway Technical Research Institute). The sectional forces of the prediction analysis results are shown in Table-1.

As a result of the prediction analysis, for the sectional forces of the segmental lining after passing the shield tunnel boring machine of the south bound line tunnel, the axial force on the adjacent side of the north bound line tunnel increases in about 40 percent, and the bending moment changed from the negative bending into a positive bend, and the maximum value decrease in about 20 percent.

Table-1 Prediction Analysis Results



3. Monitoring results and consideration

3.1 Monitoring results

The change of the value of the axial force and the bending moment of the most adjacent point is shown in Figure-3.

(1) Before passing cutter face of shield tunnel boring machine

The value of strain gauge on the segmental lining begins to change from this side where cutter face of shield tunnel boring machine passes the monitoring point six rings. The tendency from which segmental lining of the north bound line tunnel were pushed a little to the shield tunnel boring machine of the south bound line tunnel was seen while cutter face of shield tunnel boring machine was approaching.

(2) Shield tunnel boring machine passing

The deformation of the segmental lining tended to return to the origin after proceeding to excavate the shield tunnel boring machine had stopped while passing the shield tunnel boring machine though the segmental lining of the north bound line tunnel was pushed to the shield tunnel boring machine of the south bound line tunnel. This is mainly thought to be the influence of the back filling grouting injection pressure.

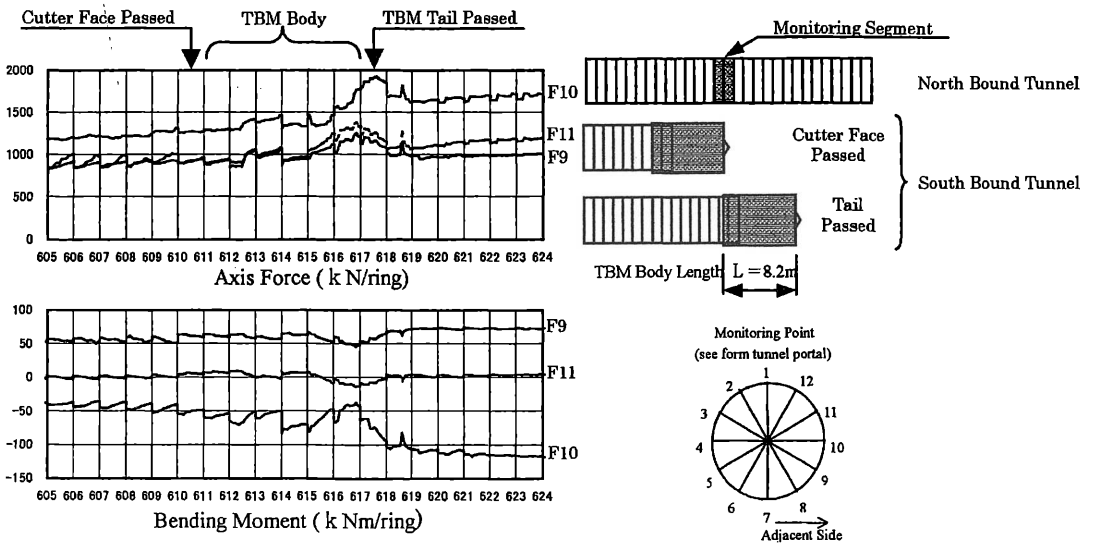
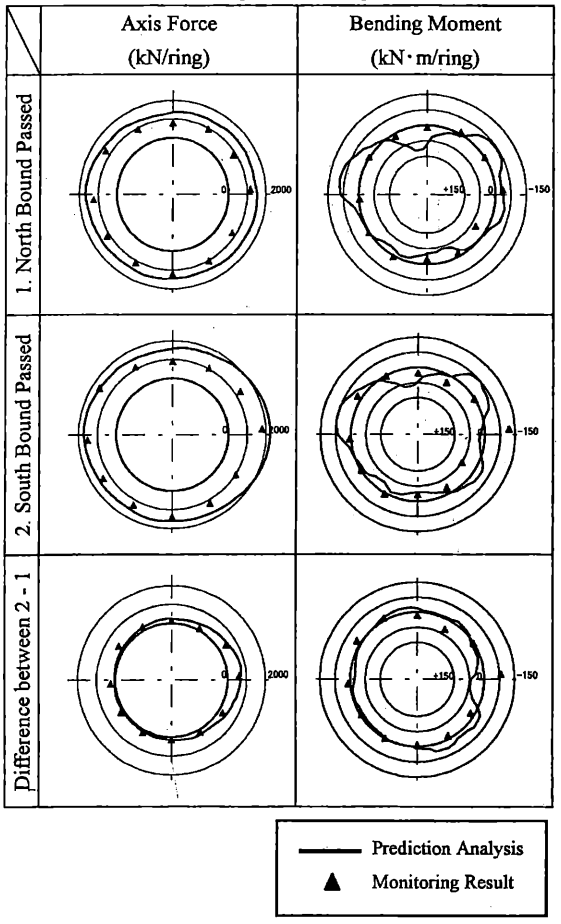


Figure-3 Axis Force, Bending Moment Graph at the Ring of Passing

(3) Tail of shield tunnel boring machine passing

The change of the sectional force grew from this side where the tail of the shield tunnel boring machine passed the monitoring point one ring, and an increase in an axial force a negative bending moment of the spring line on the south bound line tunnel side and became the maximum.

Table-2 Comparison Table of Section Force / for Segmental Lining



(4) After passing the tail of shield tunnel boring machine

After the tail of the shield tunnel boring machine had been passed, the change by proceeding to dig and the stop was seen. It is thought the influence of the back filling grouting. There was no change after five rings having passed the tail of the shield tunnel boring machine.

3.2 Comparison between monitoring and analysis result

The result of comparing the prediction analysis and the monitoring is shown in Table-2 for the influence which the super-adjacent parallel construction on the segment.

(1) Before influences with a parallel shield

Before the segmental lining is influenced with a parallel shield, maximum bending moment (=56 kNm/ring) has been generated from the spring line by 30 degrees at the position below in the monitoring result though segmental lining transforms into an oblong direction by the difference between the vertical load and the horizontal load, maximum bending moment (=117 kNm/ring) has been generated in the segment in the top part of the tunnel in the prediction analysis.

It has been understood that the difference between the vertical load and the horizontal load which acts on the segmental lining is smaller than that of a design load from the monitoring result of the axis force and the bending moment. It is thought that this is secured the segment horizontal load enough from the even action of the back filling grouting pressure on the segment, remaining of the pressure, and existed in the state to which the segmental lining is steady.

(2) After influence with a parallel shield

As for the behavior of the segmental lining after influenced by the parallel shield tunnel construction, the north bound line tunnel (preceding tunnel) was passed by transforming the south bound line tunnel (post-line tunnel) into an oblong direction through the ground of the spring line according to the prediction analysis result. Therefore, after influenced of parallel shield tunnel construction, the transformation of the spring line of the segmental lining is pushed the spring line, and has changed to the direction of a positive bend locally though the transformation of the spring line of the segmental lining before parallel construction influenced was a negative bending. On the other hand, the monitoring result shows the opposite direction of transformation to the analytical result as for the change after influenced. It is thought that this was caused by the ground reaction's of which remains between tunnels having decreased because the spacing between tunnels is small.

4. Summary

It was a result of pushing of the spring line by parallel shield tunnelling influence, and the local change of the transformation into a positive bend in the prediction analysis which preceded the construction. In the monitoring under construction, however, the transformation of the segmental lining became the extension of oblong direction.

This reason is thought that the stress liberating according to the dispersal of the injection pressure until the back filling grouting material solidifies completely is caused at the tail of the south bound line shield tunnel (post-line shield). As a result, it is thought that the ground reaction between tunnels decreased.