Settlement Reduction Effect of Advanced Back-to-Back Reinforced Retaining Wall

Koh, Taehoon†, Hwang, Seonkeun*, Jung, Hunchul** and Jung, Hyuksang***

Abstract

In order to constrain the railway roadbed settlement which causes track irregularity, and thus threatens running stability and ride quality, advanced Back-to-Back (BTB) reinforced retaining wall was numerically analyzed as railway roadbed structure. This study is intended to improve conventional Back-to-Back reinforced retaining wall as the technology which would reduce the roadbed settlement in a way of constraining the lateral displacement of its prestressed vertical facing and inducing arching effects in roadbed (backfill) placed between masonry diaphragm wall and vertical facing. As a result of numerical analysis, it was found that the roadbed settlement was reduced by 10% due to the prestressed vertical facing and embedded masonry diaphragm wall of the advanced Back-to-Back reinforced retaining wall system.

Keywords : Back-to-back (BTB) reinforced retaining wall, Prestressing effects, Roadbed settlement, Arching effects

1. Introduction

Since Casagrande introduced the concept of reinforced earth structure and Henri Vidal proposed the modernized reinforced earth structure in 1969, this method has been applied to various structures such as retaining wall, slope, foundation and embankment in line with development of reinforcement. Such growing application is attributable to advantages in cost efficiency and environmental aspect than conventional structure without reinforcement as well as superior constructability. Reinforced retaining wall with such advantages has been increasingly used since late 1990s, and has become the common structure.

Reinforced earth method has been widely applied to civil structures in Korea but has yet to be put on track in the field of railway earth structure which requires strict standards in track irregularity. Since conventional reinforced retaining wall is designed to allow lateral displacement of the wall, there is a possibility of the risk of roadbed settlement that might cause track irregularity depending on its construction condition.

This study, therefore, is intended to improve conventional Back-to-Back (BTB) reinforced retaining wall as the technology which would reduce the roadbed settlement in a way of constraining the lateral displacement of its prestressed vertical facing and inducing arching effects in roadbed (backfill) placed between masonry diaphragm wall and vertical facing.

In this study, 2D and 3D numerical analysis was carried out to evaluate the settlement reduction effect of advanced BTB reinforced retaining wall. As a result of numerical analysis, it was found that the roadbed settlement was reduced by 10% due to the prestressed vertical facing and embedded masonry diaphragm wall of the advanced BTB reinforced retaining wall system.

2. Literature Review

Fig. 1 shows the reinforced retaining wall applied to railway in Korea. Its facing is mostly the panel type. Reinforced retaining walls which have been applied to railway were mainly built at the station or sideline as low-speed area.

In Japan and North America, as part of the method to
control the long-term deformation of reinforced earth structure, preloading (PL) is applied before surcharge loads to remove the residual deformation which might occur during surcharge loads. Uchimura et al. (2003), Tat-suoka et al. (2004) and Wu et al. (2001) verified the feasibility of PL mechanism as residual deformation control method through plane strain test, model test and full scale test. Wu et al. (2001) particularly introduced preloading to the reinforced retaining wall of roadway bridge abutment, and Yoo et al. (2005) studied on the effect of constraining residual deformation by PL method when using weathered granite soil as backfill material through plane strain test and model test.

However, the lack of study on optimal load in applying PL method gives rise to the confusion in design and installation.

In this study, optimal load in applying PL method to constrain the deformation resulting from train load was evaluated. And settlement reduction effect on the roadbed by the advanced BTB reinforced retaining wall was verified through numerical analysis.

### 3. Numerical Analysis

3D finite element analysis was performed to estimate the prestressing effects on the vertical facing of the segmental retaining wall. 2D finite element analysis was adopted to estimate the arching effects on the behavior of the railway roadbed by the advanced BTB reinforced retaining wall system.

#### 3.1 Analysis condition

6 m height (H) segmental retaining wall was considered as the reinforced structure for numerical analysis. The length of geogrid was determined as 4.2 m corresponding to 0.7H which is appropriate to design standard, and its vertical spacing was 0.8 m. 50 kN/m² was applied to the surface of the roadbed as design load. Details of reinforced retaining wall are indicated in Fig. 2.

MIDAS/GTS(Geotechnical and Tunnel analysis System) was used as a FEM analysis program. Construction of reinforced retaining wall was simulated same as actual construction condition.

#### 3.2 Material properties

Mohr-Coulomb elasto-plastic model was implemented to simulate the behavior of the roadbed (backfill). And linear elastic model was used for facing (concrete segmental retaining wall) and concrete foundation.

Material properties of geogrid applied in this study were determined in accordance with wide-width strip tensile strength test (Korea Institute of Construction Technology, 1999). Deformed bar (D22) as a tendon was installed to apply the prestress to vertical facing of the reinforced retaining wall structure. Summary of material properties is shown in Table 1.

#### 3.3 Analysis results

When introducing prestress to the geotechnical structure such as the retaining wall receiving out-of-plane load, rapid failure is anticipated when out-of-plane load such as earth pressure exceeds the introduced prestress and thus, in order to impose tensile force to prevent the overturn failure of the structure, structural stability of segmental vertical facing was evaluated using 3D numerical analysis depending on variation of preload which simulates the tensile force applied to the location of tendon.

To that end, modeling of actual shape of segmental vertical facing and load condition are shown in Fig. 3 and Table 2.

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**Fig. 2** Numerical analysis section for BTB reinforced retaining wall

**Table 1.** Summary of material properties

<table>
<thead>
<tr>
<th>Classification</th>
<th>Unit Weight (kN/m³)</th>
<th>Elastic Modulus (MPa)</th>
<th>Cohesion (kPa)</th>
<th>Friction Angle (°)</th>
<th>Poisson’s Ratio</th>
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<tbody>
<tr>
<td>Roadbed (Backfill)</td>
<td>19.0</td>
<td>30</td>
<td>1.0</td>
<td>30</td>
<td>0.30</td>
</tr>
<tr>
<td>Concrete Facing</td>
<td>23.0</td>
<td>23,000</td>
<td>-</td>
<td>-</td>
<td>0.15</td>
</tr>
<tr>
<td>Concrete Foundation</td>
<td>24.5</td>
<td>23,000</td>
<td>-</td>
<td>-</td>
<td>0.15</td>
</tr>
<tr>
<td>Geogrid (Reinforcement)</td>
<td>-</td>
<td>1,000</td>
<td>4.0</td>
<td>-</td>
<td>0.20</td>
</tr>
<tr>
<td>Tendon (Deformed bar)</td>
<td>78.5</td>
<td>210,000</td>
<td>-</td>
<td>-</td>
<td>0.30</td>
</tr>
</tbody>
</table>
As a result of 3D numerical analysis, preload 333.33 kN introduced to the segmental vertical facing considered in this study exceeded allowable bending compressive stress (9.6 MPa) of segmental vertical facing, and maximum compressive stress was concentrated on its back side.

Fig. 4 is the resultant bending compressive stress on the vertical facing for each introduced preload, and Fig. 5 shows the stress distribution on vertical facing for preload 300 kN.

3.3.1 Prestressing Effects on Vertical Facing
2D numerical modeling and load condition are shown in Fig. 6 to evaluate the prestressing effects on the conventional BTB reinforced retaining wall by applying preloads to the vertical facing.

3.3.2 Arching effects of the Advanced BTB Reinforced Retaining Wall
To reduce the roadbed settlement of the railway roadbed structure, advanced BTB retaining wall in this study adopted the masonry diaphragm wall between vertical fac-

<table>
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<th>Table 2 Load conditions</th>
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<tr>
<td>Classification</td>
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<td></td>
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<tr>
<td>Preload (kN)</td>
</tr>
</tbody>
</table>

Fig. 3 3D modeling of segmental vertical facing

Fig. 4 Resultant bending compressive stress on vertical facing

Fig. 5 Stress distribution on vertical facing for preload 300 kN

Fig. 6 Modeling of conventional BTB reinforced retaining wall
The masonry diaphragm wall installed between vertical facings induces arching effects in roadbed (backfill) placed between masonry diaphragm wall and vertical facing. The reduction of roadbed settlement is expected by the bearing capacity increased due to the arching effects induced in roadbed.

Based on the results of 2D numerical analysis as shown in Fig. 10, roadbed settlement of the advanced BTB reinforced retaining wall (settlement of 3.84 mm) was reduced by 10% due to the prestressing effects on the vertical facing and arching effects in roadbed as well comparing with the conventional BTB reinforced retaining wall system (settlement of 4.26 mm).

4. Conclusion

In order to constrain the railway roadbed settlement which causes track irregularity, floating sleeper and thus threatens running stability and ride quality, Advanced Back-to-Back reinforced retaining wall system was numerically
analyzed as railway roadbed structure.

Advanced Back-to-Back reinforced retaining wall system can deal with the railway roadbed settlement since it introduces prestress to conventional Back-to-Back reinforced retaining wall and induces arching effects in roadbed by the adopted masonry diaphragm wall between vertical facings as well. The following conclusions can be drawn from this study.

1) As a result of 3D numerical analysis, preload 300kN introduced to the segmental vertical facing considered in this study is the maximum value to satisfy with its allowable bending compressive stress (9.6 MPa).

2) Due to the preload (300 kN) introduced to the vertical facing, its lateral displacement was reduced by 77% at the top of the facing and 10% at the location (0.6 H) which maximum resultant lateral displacement occurred.

3) Comparing with the conventional Back-to-Back reinforced retaining wall, roadbed settlement of the advanced Back-to-Back reinforced retaining wall was reduced by 10% due to the prestressing effects on the vertical facing and arching effects in roadbed as well.

References