Behaviour characteristic of convex for geosynthetic retaining wall according to curvature radius

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ABSTRACT: The reinforced soil retaining wall is one of the civil structures that people who living in the city can come into closely such as foundation, slope, road, etc. Studies on reinforced soil retaining wall method have been carried out variously according to the development of back-fill or reinforcement materials, and there are multiple design standards to ensure structural stability. However, most of them have limitations that have not considered curved part of reinforced soil retaining walls, which is the weakest point of wall, as under two-dimensional plane-strain conditions. In this study, therefore, the convex part of the reinforced soil retaining wall was modeled via three-dimensional numerical analysis and the behaviour characteristics corresponding to the curvature of the curved part of the one was compared with the straight part and analyzed. As a result, the horizontal displacement and settlement for convex part greater occurred than straight and the closer straight to curved part, the reduction of deviatoric stress are increased.

Keywords: Geosynthetic retaining wall, Convex type, Curvature radius, Numerical analysis, Stress path

1 INTRODUCTION

Retaining walls are one of the various infra-structures closely related to our daily life and commonly found in roads, railways, bridges, and complexes. The stability to back earth pressure increases the available space for us and maximizes the efficiency of transportation, industries, residences, etc. In particular, the geosynthetic reinforced retaining wall is one of the methods to obtain structural stability and economy by improving the shortcomings of general reinforced concrete (RC) retaining wall, through high-cut slope height and easy constructability. Its behaviour in curved sections, however, has not yet been quantified, and but also, according to many damage reports, most of damages to them such as excessive displacement, inclusive of excessive crack and settlement occur in concentration at curved part of the wall. In order to solve these problems for curved part, improved construction technology such as compaction of fill or installation of reinforcement have been required, so far.

This study simulated the curved section of geosynthetic reinforced retaining wall through three-dimensional (3D) numerical analysis and compared lateral displacement by the curvature radius of the curved section. The authors are producing equipment for laboratory model test and have planned to perform field tests in order to quantitatively analyse the behaviour of geosynthetic reinforced retaining walls according to curvature radius as well as angle and height.

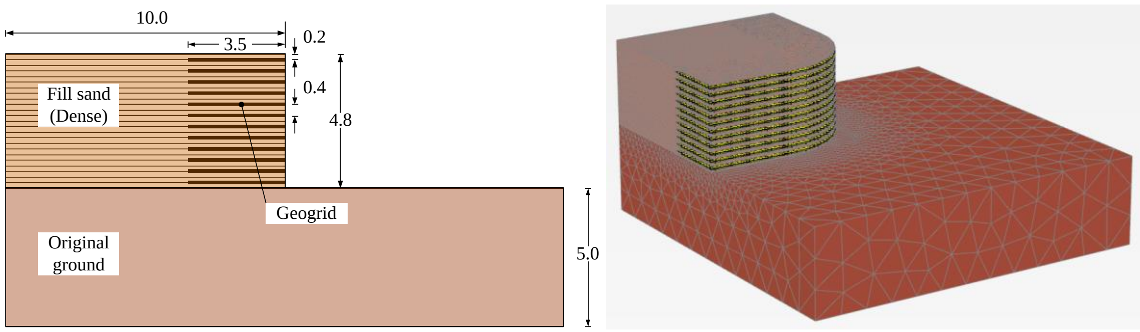
2 LITERATURE REVIEW

Many geosynthetic reinforced retaining wall in Korea have been developed, but most are designed in accordance with the design guideline of the Federal Highway Administration (FHWA). However, various accident cases have been reported due to factors that cannot be considered through design guidelines (Yoo et al., 2005). Currently, the geosynthetic reinforced retaining walls within and outside South Korea are analysed by the two-dimensional (2D) plane-strain condition, which has the limitation of not considering the shape of the reinforced retaining wall. Furthermore, Kim et al. (1998) researched the curved section of reinforced retaining wall through finite element analysis. However, none of these studies considered the curvature radius of the curved section of the reinforced retaining wall. Ki et al. (2012) analysed the displacement of the front wall after classifying the shapes of reinforced retaining walls into concave and convex types through laboratory model tests. According to this study, both concave and convex types had large lateral displacements at the centre of the curved section. The present study, therefore, conducted a numerical analysis to compare the lateral displacements of the straight and curved sections and the settlement of the back surface according to the curvature radius of a convex reinforced retaining wall. The stress paths of the straight and curved sections at the same height were also compared through the p-q diagram ($p = \frac{(\sigma_1 + \sigma_2 + \sigma_3)}{3} = \frac{\sigma_1 + 2\sigma_3}{3} (\because \sigma_2 = \sigma_3)$, $q = \frac{\sigma_1 - \sigma_3}{2}$).

3 NUMERICAL ANALYSIS

3.1 *Modelling*

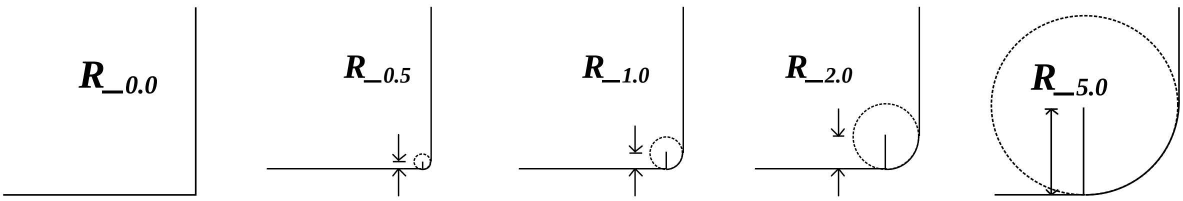
In this study, the height of the geosynthetic retaining wall was assumed to be 4.8 m. In addition, it was assumed that the fill sand layer was filled in 0.2 m intervals and one reinforcement was installed per 0.4 m (Fig. 1).



(a) Modelling mimic (b) Mesh generation

Figure 1. Modelling for numerical analysis

In every case, the angle of the reinforced retaining wall was assumed to be 90°. The horizontal stress of the actual reinforced retaining wall that resist the back-earth pressure can include the friction force of the soil and reinforcement and the friction force between the reinforced retaining wall blocks. However, as this is a fundamental study on the behaviour of the curved section of geosynthetic reinforced retaining wall, the present study did not simulate the walls in order to not consider the friction force between the blocks. Each case was distinguished by the curvature of the curved section of wall. The curvature radius was assumed to be 0.0 m, 0.5 m, 1.0 m, 2.0 m, and 5.0 m for cases 1 to 5, respectively (Fig. 2).



(a) Case 1 (b) Case 2 (c) Case 3 (d) Case 4 (e) Case 5

Figure 2. Cases for numerical analysis

3.2 *Material properties*

As mentioned in the previous section, the fill sand soil for the back of the geosynthetic reinforced retaining wall was considered as dense soil. For the dense soil, 70% of relative density was applied, and for the unit weight and void ratio to represent it in the numerical analysis, the values were suggested by Kim et al. (2012). Kim et al. (2012) researched the behavioural characteristics of Joomunjin standard sand through repeated triaxial compression tests. For the cohesion, shear resistance angle, Young's modulus, and Poisson's ratio, the values in the Principle of Geotechnical Engineering of Das (2009) were used. To reduce the settlement of the soil below the reinforced soil, the material properties of general soil were applied to original ground. For the geogrid used in the reinforced soil, the property of the general geosynthetic fibre reinforcement (EA=50 kN/m2) was applied (Yoo et al. 2014). The material properties of the soils used in this study are shown in Table 1.

Table 1. Material properties

Classification	Unit	Fill sand (Dense)	Original ground
Constitutive model	Mohr-coulomb model		
Unit weight (γ)	kN/m^3	15.88	20.00
Young's Modulus (E)	kN/m^2	40e3	300e3
Poisson's ratio (v)	-	0.3	0.33
Friction angle (ϕ)	deg	35	35
Cohesion (c)	kPa	15	50
Void ratio (e)	-	0.712	0.5
Dilatancy angle (ψ)	deg	5	5

4 RESULTS

This study compared the max lateral displacement and occurrence points and p-q diagram in the straight and curved sections in each case according to the curvature radius of the curved section of reinforced retaining wall.

The lateral displacements of straight and curved sections are shown in Fig. 3. In the straight section, a lateral displacement of approximately 8.1 mm occurred, which did not show significant differences in all cases. In the curved section, the maximum lateral displacement of approximately 9.13 mm occurred in case 1. Furthermore, the lateral displacements in cases 2 and 3 were approximately 9.12 mm and 9.08 mm, whereas they were 8.72 mm and 8.66 mm in cases 4 and 5, respectively. In other words, when the curvature radius increased from 0.0 m to 1.0 m, the maximum lateral displacement decreased by approximately 0.01 %–0.04 %, but when the curvature radius increased to 2.0 m, the maximum lateral displacement decreased by approximately 11.5 %. After that, when the curvature radius increased to 5.0 m, the reduction rate of the maximum lateral displacement was 0.6 % (Fig. 4).

The settlements of the back surface of reinforced retaining wall in each case are shown in Fig. 5. In the straight section, the settlement of surface increased as it was closer to the wall, and the maximum settlement of approximately 4.8 mm occurred. Similarly, the settlements in the cases of curvature radii of 0.0 m, 0.5 m, and 1.0 m also increased as it they were closer to the wall, and the maximum settlement was approximately 8.1 mm, which showed no significant differences. However, in the cases of curvature radius of 2.0 m and 5.0 m, the settlements were 7.85 mm and 7.81 mm, respectively (① in Fig. 5). As with the maximum lateral displacement, the settlement reduction rate was the largest at approximately 3 % when the curvature radius was 2.0 m (② in Fig. 5).

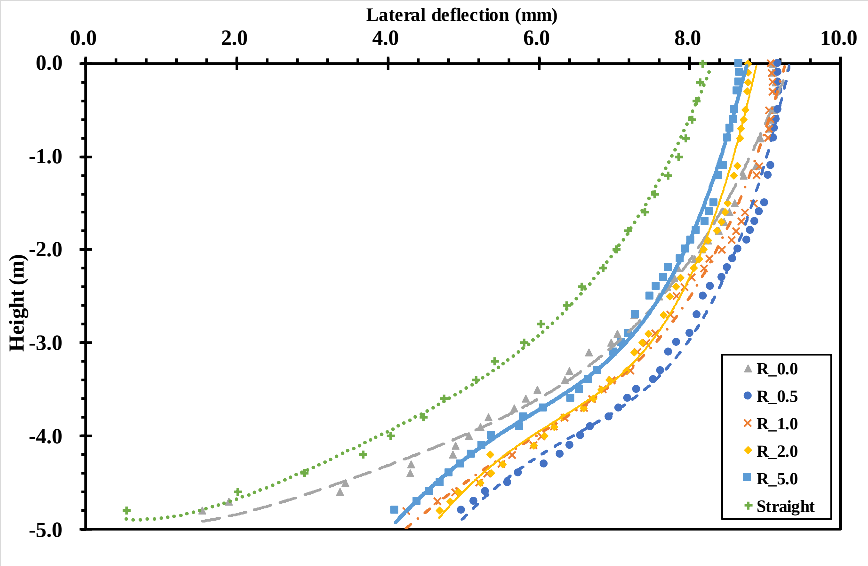


Figure 3. Lateral deflection

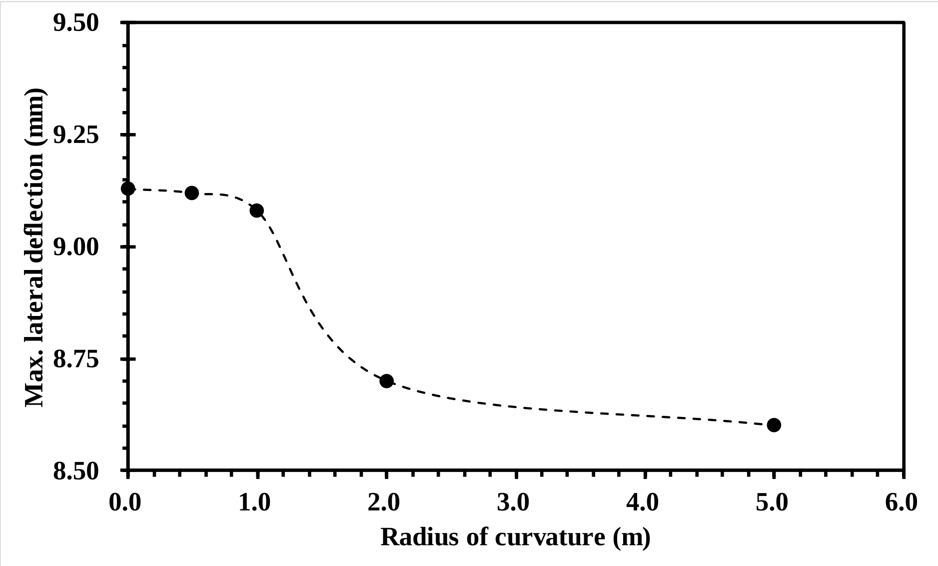


Figure 4. Maximum lateral deflection-radius of curvature

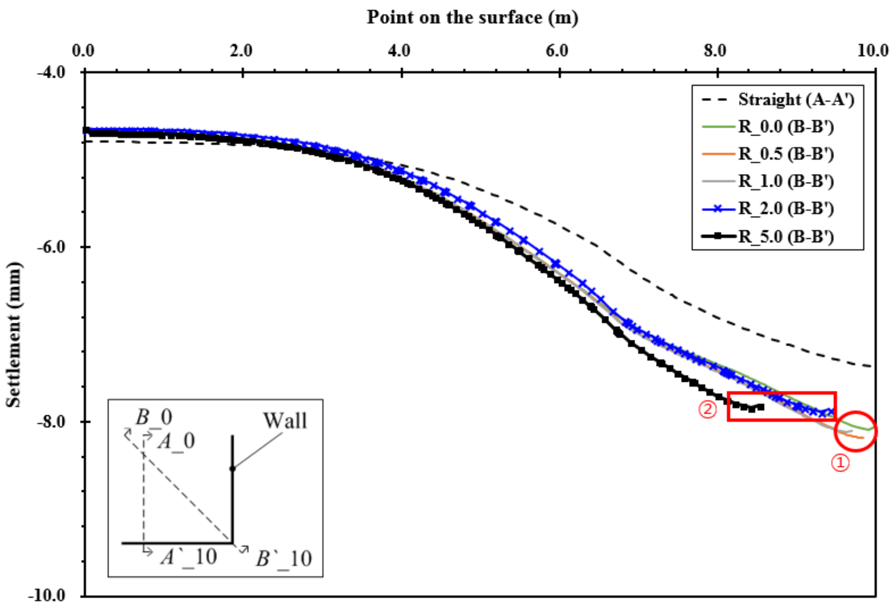


Figure 5. Settlement of surface

The stress path depending on closeness from the straight section to the curved section of the reinforced retaining wall at approximately 3.4 m from the bottom is shown as a p-q diagram in Fig. 6. In every case, the stress path moved to the upper left as it was closer from the straight section to the curved section. This was similar to the trend of unloading-compression in the triaxial compression test in Atkinson (2007). This means that since is constant in every case ($\Delta\sigma_v = 0$), σ_h decreases as it gets closer from the straight section to the curved section. Furthermore, $-\Delta\sigma_h$ was the largest in case 4 (R_2.0). $-\Delta\sigma_h$ was 1.87 kPa, 2.73 kPa, 2.76 kPa, 4.02 kPa, and 2.46 kPa in cases 1 to 5, respectively. This stress path is considered to be the factor that decreases the lateral displacement the most in case 4.

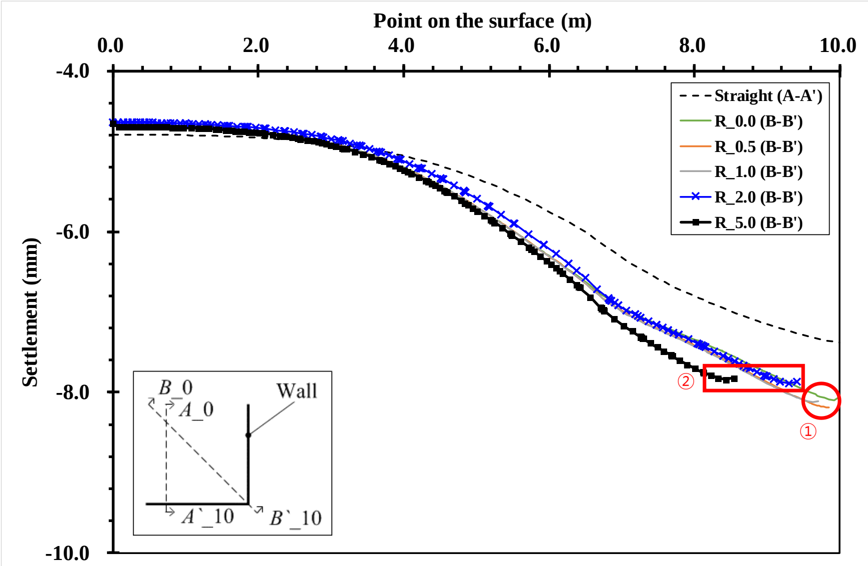


Figure 6. Stress path at straight and curved part

5 CONCLUSIONS

This study analysed the behaviour characteristics of the curved section of geosynthetic reinforced retaining wall depending on the curvature radius, through a three-dimensional numerical analysis. The wall face was not modelled because it was assumed that it cannot resist the back-earth pressure, and the angle and height of the curved section were assumed to be 90° and 4.8 m, respectively. Analysis was performed by classifying the curvature radii into 0.0 m, 0.5 m, 1.0 m, 2.0 m, and 5.0 m, and the lateral displacement, the settlement of back surface, and the *p-q* diagram of each case were analysed.

Regardless of the curvature radius, the maximum lateral displacement of the wall was larger in the curved section than in the straight section, and as the curvature radius increased, the maximum lateral displacement of the curved section decreased. Furthermore, when the curvature radius was 2.0 m, the maximum lateral displacement of the wall in the curved section decreased by approximately 11 %, indicating the largest decrease compared to other cases.

As with the lateral displacement of the wall, the settlement of back surface was also larger in the curved section than in the straight section regardless of the curvature radius. The settlement decreased by approximately 3 % when the curvature radius was 2.0 m, indicating the largest reduction compared to other cases.

The stress path, as it was closer from the straight section to curved section, was analysed in a *p-q* diagram, and every case showed the unloading-compression condition. In case 4, the lateral stress decreased by approximately 4.02 kPa.

This is a fundamental study on the behaviour characteristics of the curved section of reinforced retaining wall. Laboratory model tests and field measurements will be performed as well as numerical analysis in future studies.

ACKNOWLEDGMENT

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