Geosynthetics, J. Kuwano & J. Koseki (eds)
© 2006 Millpress, Rotterdam, ISBN 90 5966 044 7

Case study on the global slope failure with geogrid reinforced soil wall

Han, J.G., Kim, J.S. & Hong, K.K.
Department of Civil & Environmental Engineering, Chung-Ang University, Korea

Cho, S.D. & Lee, K.W.
Department of Geotechnical Engineering, Korea Institute of Construction Technology, Korea

Jeong, S-S.
Department of Civil Engineering, Yonsei University, Korea

Keywords: SRW, reinforced soil wall, global slope failure, tiered wall, slope stability analysis

ABSTRACT: This paper describes a case study on global slope failure in a tiered geogrid reinforced soil wall. Site investigations and slope stability analyses were conducted to investigate the causes of the collapse. The collapsed history with the regional rainfall records indicates that the decrease of the bearing capacity in foundation ground induced by seepage of rainwater was one of causes of the collapse. The other reason of the collapse was the increasing of the active forces in the slope induced by pile driving on the embankment slope. These results were confirmed by slope stability analyses with considering rainfall and construction stages respectively.

1 INTRODUCTION

The geosynthetic reinforced soil walls, which have advantages such as economical efficiency, graceful appearance and easy construction, are replacing the conventional retaining wall increasingly. In Korea, both internal and external stabilities for the reinforced soil walls are estimated by the design guidelines specified in FHWA (Elias & Christopher, 1996) or NCMA (Collin, 1997). However, the global slope stabilities of the reinforced soil walls are used to be overlooked frequently during design for the reinforced soil walls. The inappropriate design practice causes severe damages such as partial and entire collapse of the wall or severe horizontal displacement of the wall facing. These troubles have occurred frequently in the curved section of the wall structure or a tiered wall with high height (Cho, 2001).

This paper describes a case study on global slope failure in a tiered geogrid reinforced soil wall with 22 m in maximum height. This case study includes the investigation of the failure causes by the site investigations and the slope stability analyses.

2 COLLAPSED WALL

2.1 *Site description*

During the construction of the highway, blocktype geogrid reinforced soil wall was being constructed in near the bridge abutment section. Figure 1 is geographical features of the site.

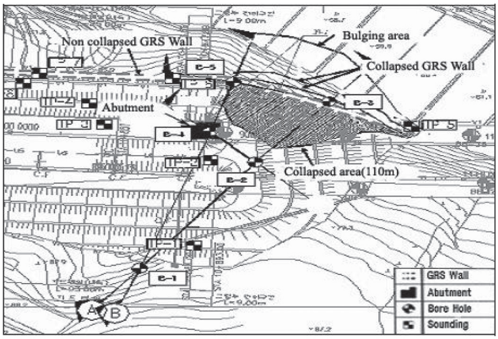


Figure 1. Plan view of the site.

The reinforced soil wall was 167 m in length, 1,800 m^2 in facing area and 22 m in maximum height. The embankment slope was constructed above the wall as shown in Figure 2. The maximum height of the entire slope including the wall was about 32 m. After completing the embankment slope, piled bridge abutment is constructed. The abutment is supported by steel pipe piles with 508 mm in diameter. The PET(polyester) geogrids were used as reinforcements.

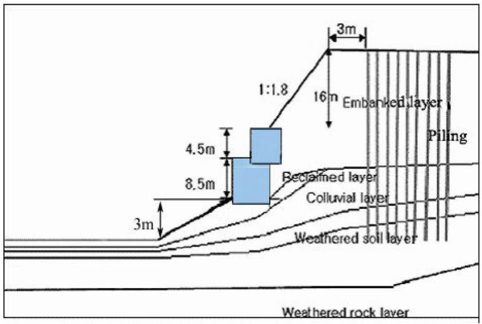
2.2 *Situation of the collapse*

The collapse of the structure occurred at slope with geogrid reinforced soil wall during pile driving for the abutment foundation as shown in Figure 2. Figure 3 shows two representative cross sections of the structure with soil profile at the collapsed area. The

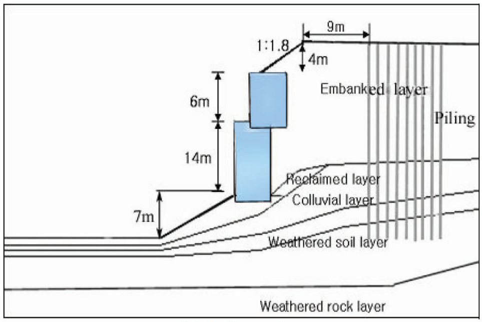
Figure 2. Photo of collapse in the reinforced soil wall.

locations of two sections, A-A and B-B section, are shown in Figure 1. The original ground existing under the embankment is composed of reclaimed soil, colluvial soil, weathered soil and weathered rock respectively as shown in Figure 3. The colluvial layer is composed of clay and sandy gravel. The soil properties are shown in Table 1.

Figure 4 shows the situation at the time of the collapse. Total 34 piles were planned to install to support the abutment. The global slope failure occurred at No. 5 pile driving which was twentieth pile driving.



(a) A-A section



(b) B-B section

Figure 3. Cross section before the collapse.

3 CAUSES OF THE COLLAPSE

Site investigations and slope stability analyses were conducted to investigate the causes of the collapse. As first step, the regional rainfall records with elapsed time were compared with the collapsed history, and then the slope stability analyses were performed on the embankment slope with reinforced soil wall, which was located in the collapsed area.

3.1 *Influence of rainfall*

In June 24, some cracks were found firstly at the facing blocks of the wall. Figure 5 shows the collapsed history with the regional rainfall records. The cracks were more progressed slightly until July 5, and then stopped until August 8.

Although it rained heavily at July 4 and July 14, 90 mm/day and 176 mm/day respectively, the length

Table 1. Summary of soil properties.

Layer	Test method		c (N/m^2)	ϕ (°)	Es (N/m^2)	k (m/s)
Embankment and Reclaimed soil	S.P.T		–	28.0 ~31.7	9257 ~38442	1.38×10^{-6} ~1.37×10^{-6}
	test	Lab	4.9	41.4	–	
		Site	1.18	36.7	–	
Colluvial soil		S.P.T	–	30.9 ~35.5	13876 ~57663	3.61×10^{-6} ~3.72×10^{-6}
	test	Lab	10.9	36.8	–	
		Site	1.47	33.2	–	
Weathered soil		S.P.T	–	26.0 ~46.6	6609 ~137293	3.29×10^{-6} ~1.15×10^{-6}
	test	Lab	12.7 ~21.6	26.6 ~31.9	–	
		Site	14.7	26.3	–	

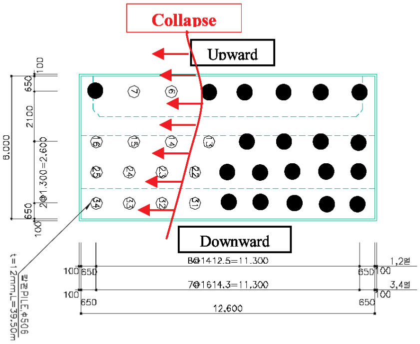


Figure 4. Situation of installation of foundation piles.

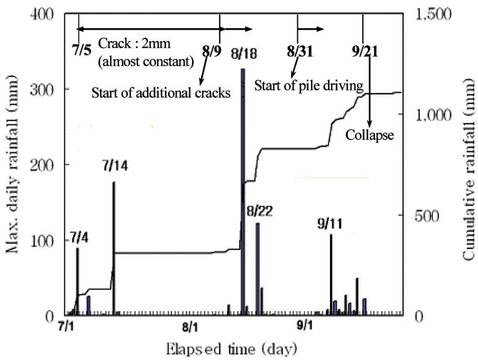
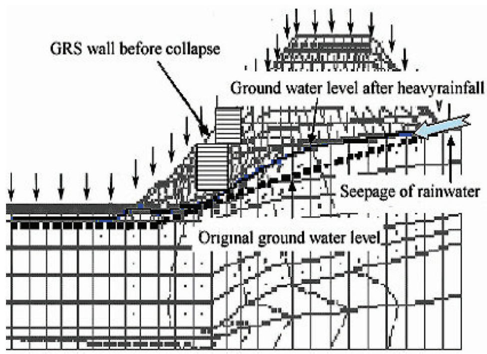


Figure 5. Collapsed history with rainfall record.

of cracks was very slightly increased during about 30 days after the heavy rainfall. However, additional cracks were observed again at August 9. These occurrences of cracks mean a sign of failure induced by seepage of the rainwater through the colluvial layer as shown in Figure 6. The colluvial soil has large permeability as shown in Table 1. The seepage induced the decrease of the bearing capacity in foundation ground. Moreover, the bearing capacity of the foundation might be decreased severely by additional heavy rainfalls at August 18 (328 mm/day) and August 22 (122 mm/day). The decrease of



Figrue 6. Seepage of rainwater and change of ground water level.

the bearing capacity of the foundation might induce not only the differential settlement of the foundation ground but also the decrease of the resisting forces against the slope failure. Furthermore, pile driving, which was begun at August 31, might be worked as active forces in the slope. As a result, there were two inferences to be drawn from the collapsed history with rainfall records. One was the decrease of the resisting forces induced by the seepage of rainwater and the other was the increment of the active forces by pile driving.

3.2 *Global slope stability analysis*

The slope stability analyses, which considered influences of both rainfall and construction stages, were performed on both A-A and B-B section of the slope shown in Figure 3. The slope stability analyses considering rainfall were conducted by using SLOPILE 3.0 program, while the analyses considering construction stages were performed by using PLAXIS 7.0 program. The material parameters used in the analysis are given in Table 2.

The results of the analyses are illustrated as following sections.

3.2.1 *Slope stability considering rainfall*

In order to estimate the influence of the rainfall, the slope stability analyses with different groundwater

Table 2. Summary of material parameters in the analysis.

Layer	Model	γ_t (kN/m^3)	c (N/m^2)	ϕ (deg)	Es (N/m^2)	ν	I.S.F.
Facing block	L.E	23.5	–	45.0	2.53 × E7	0.25	–
Pile	L.E	23.2	–	–	1.66 × E7		
GRS body	M.C	18.6	19.6	35.0	1.37 × E5	0.3	–
Embankment soil	M.C	18.6	4.4	35.0	3.84 × E4	0.3	0.5
Surface	M.C	19.6	1.2	30.0	3.84 × E4	0.35	0.5
Colluvial soil	M.C	18.6	1.5	33.2	5.76 × E4	0.4	0.5
Weathered soil (1)	M.C	18.6	14.7	26.3	8.23 × E4	0.3	0.5
Weathered soil (2)	M.C	18.6	14.7	32.0	1.37 × E5	0.2	1.0
Weathered Rock	M.C	21.6	2.0	38.0	2.94 × E5	0.2	1.0

* L.E : Linear-Elastic, M.C : Mohr-Coulmb

levels were performed by Bishop simplified method. From the results of site investigation after the collapse, it was found that the original groundwater level was distributed between colluvial soil layer and weathered soil layer. However, the groundwater level can be risen upward by the seepage of rainwater as shown in Figure 6. Therefore, the analyses of slope stability were performed on three different ground water levels, which are distributed in the central part of colluvial soil layer, the surface of colluvial soil layer and the surface of reclaimed soil layer shown in Figure 3 respectively.

The results of the analysis are presented in Table 3. The safety factor of slope was larger than 1.2 in case of the analysis on A-A section. However, in case of B-B section, the safety factor of slope was less than the required safety factor of slope, 1.2, and decreased with the rise of the groundwater level.

Table 3. The results of slope stability analysis considering rainfall.

Groundwater level	Safety Factor of slope	
	A-A section	B-B section
central part of colluvial layer	1.35	1.14
surface of colluvial soil layer	1.35	1.10
surface of reclaimed soil layer	1.22	0.94

Especially, when the ground water level was distributed in the surface of reclaimed soil layer, the safety factor of slope was less than 1.0, which is the critical safety factor of slope. This means that the slope is very unstable so as to generate sliding failure in slope.

3.2.2 *The slope stability with construction stages*

The safety factor of the collapsed slope according to the construction stage was estimated by numerical analysis using general FEM program PLAXIS 7.0. The results of the analysis are presented in Table 4. The results of the numerical analysis were similar to the results of the slope stability analysis considering groundwater levels. The safety factor of slope was larger than 1.2 in case of the analysis on A-A section. However, in case of B-B section, the safety factor of slope was less than the required safety factor of slope after the completion of the upper wall. After the construction of the upper wall, the safety factor of the slope with reinforced soil wall was near in critical safety factor of slope. Moreover, it was found that the repeat of the pile driving cause the decrease of the slope safety factor. This means that the slope with reinforced soil wall is unstable.

Table 4. Variation of slope safety factor of the slope with the construction stages.

Construction stage		Safety factor of slope	
		A-A section	B-B section
Completion of lower wall		1.607	1.214
Completion of upper wall		1.277	1.003
Twentieth	1st driving	1.263	1.012
pile driving	3rd driving	1.264	1.011
	5th driving	1.268	1.010

4 CONCLUSIONS

The global slope failure occurred at a slope with geogrid reinforced soil wall during pile driving for the abutment foundation constructed on the embankment slope. Site investigations and slope stability analyses were conducted to investigate the causes of the collapse.

The collapsed history with the regional rainfall records indicated that the seepage of rainwater was one of the causes of the collapse. The seepage of the rainwater induced the decrease of the bearing capacity in foundation ground. The decrease of the bearing capacity might induce not only the differential settlement of the foundation ground but also the decrease of the resisting forces against the slope failure. Furthermore, the pile driving forces acting on the embankment slope induced the increasing of the active forces in the slope with reinforced soil wall. These results were confirmed by slope stability analyses with considering rainfall and construction stages respectively.

ACKNOWLEDGEMENTS

This research was supported by the Industrial and Academic Cooperation Grants in 2005.

REFERENCES

Cho, S.D. (2001), “Application and Outlook of Geosynthetics-Reinforced Earth Wall in Korea”, Outcome of TC9 Activities of ISSMGE (1998-2001), pp. 40-41.

Collin, J. (1997). “Design Manual for Segmental Retaining Walls, 2nd Ed.” NCMA, Virginia.

Elias, V. and Christopher, B.R. (1996), “Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Design and Construction Guidelines”, FHWA Demonstration Project 82, Washington, DC.

