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Numerical Simulations of Geosynthetics-Reinforced Soil Slopes With and Without Wrapping Facing Under Displacement Load

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ABSTRACT

Geosynthetics–reinforced structures are widely used in embankments and walls. The stability of the slope is improved by the friction between the reinforcement and the backfill. Thus, stabilization of soil is achieved in order to resist the earth pressure. In this paper, finite element analyses are performed to compare the displacements at the surface of the geosynthetics–reinforced slopes with and without the wrapping facing under load pressure, and the stability of geosynthetics–reinforced slopes with wrapping facing under different slope ratio such as 1:1.5, 1:1 and 1:0.5. The results show that reinforcement can suppress the displacement effectively, and the geosynthetics–reinforced slopes with wrapping facing have more significant effect than slope without wrapping facing. As the slope ratio of the geosynthetics–reinforced slopes increased, the displacements also increased and conce2ntrated at the bottom of the slope.

Key words: numerical simulation; wrapping facing; displacement; deformation behaviors; geosynthetic-reinforced slope; slope

1. INTRODUCTION

Geosynthetic-reinforcing technologies are receiving increasing attention in the civil engineering community, this is mostly due to highly cost-effective performance and can mitigate slope failure caused by vertical loads of such as, vehicles, embankments and architectural structure. Leshchinsky and Boedeker (1989), presented an analytical approach for the stability analysis of the reinforced slopes based on the limit equilibrium theory. Some researchers performed stability analysis of slopes using finite element

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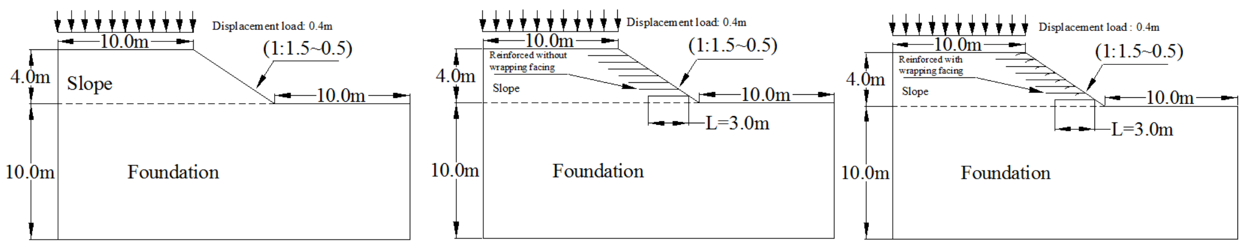
method(FEM), and they conducted stability analysis of slope by means of shear strength reduction technique in finite element method(FEM), (Griffiths and Lane ,1999; Dawson, 1999). Tatsuoka and Kongkitkul (2004) reported that the strength and stiffness of reinforced soil increases with an increase in the confining pressure caused by the reinforcement. Rostami and Ghazavi (2015) researched the ultimate bearing capacity of sand reinforced slope has some connection with number of geogrid layers, soil properties and the slope angle. According to Luan and Wu (2003), this study was used displacement control method and simulated loading by applying a vertical downward displacement load to the whole crest of the slope, and comprehensive analysed the criterion instability by penetration of the plastic point and the obvious displacement occurred in the slope surface.

This paper describes the shape and magnitude of deformation behaviors at the surface of the geosynthetic-reinforced soil slope with and without the wrapping facing under the load pressure. The finite element model of geosynthetic-reinforced slope under three cases slope ratio such as 1:1.5, 1:1 and 1:0.5 were assumed, and be presented in Fig.1 and Table 1.



a) Case 1, 4, 7 b) Case 2, 5, 8 c) Case 3, 6, 9

Fig.1 The dimension of the unreinforced and reinforced slopes with and without wrapping facing

TABLE 1— Cases of finite element model

Slope ratio		Unreinforced slopes	Reinforced slopes without wrapping facing	Reinforced slopes with wrapping facing	Displacement load
1:1.5 (*V*:*H*)	Case1	√	–	–	0.4m
	Case2	–	√	–	0.4m
	Case3	–	–	√	0.4m
1:1.0 (*V*:*H*)	Case4	√	–	–	0.4m
	Case5	–	√	–	0.4m
	Case6	–	–	√	0.4m
1:0.5 (*V*:*H*)	Case7	√	–	–	0.4m
	Case8	–	√	–	0.4m
	Case9	–	–	√	0.4m

2. NUMERICAL MODELING

Slope height is 4m and having 7 layers of reinforcement spaced 0.5m as shown Fig.1 (b), (c). The top of the slope length is 10m in order to eliminate the boundary effect. The reinforcement length is 3m and the face wrap length is 1.2m. Foundation height and length in front of the slope surface are both 10m. The slope and foundation were assumed to granular soil, the property of the soil and reinforcement materials are presented in Table 2.

TABLE 2—Soil and reinforcement material properties

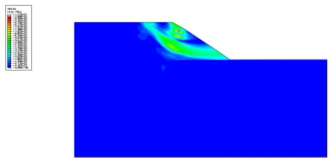
Property / Material	γ (kN/m^3)	c (kPa)	φ (°)	E (kPa)	v (%)
Slope	19	15	25	10000	0.35
Foundation	19	15	30	20000	0.33
Reinforcement	–	–	–	2500000	0.33

Slopes were modeled as elastoplastic material with Mohr-Coulomb constitution relation. This paper used the disposable backfill and ignored the influence of the backfill by layers due making simple . Reinforcements were modeled as a linear-elastic material and embedded in the slopes.

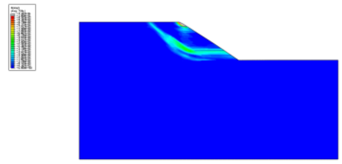
3. RESULTS AND DISCUSSION

3.1 Influence of the reinforcement

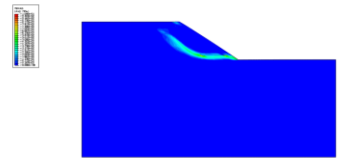
Fig.2 showed the plastic point of the slopes under the displacement load, the developed trends of plastic point are similar that start at the toe of the slope and developed to the top more concentrated to the center, with a certain degree of curvature, this coincides with the Luan and Wu (2003) reported similar results. In the unreinforced slope, a lot of plastic point was existed in the region near the slope surface, made the slope unstable. Compare the unreinforced slopes, in the reinforced zone, due to the reinforcement, the plastic point disappeared essential in the reinforced slope without wrapping facing, however, little plastic point existed neared the slope surface. Compare the reinforced slope without wrapping facing, due to the wrapping facing, the plastic point disappeared essential near the slope surface in the reinforced slope with wrapping facing, and in Case 9 a lot of plastic point near the slope toe, result from in this slope ratio, the reinforcement with wrapping facing made the slope to be a whole mass, entirety downward when been applied by loading.



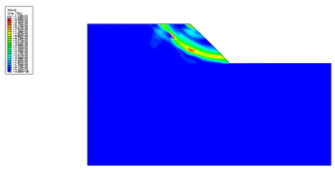
a) Case 1



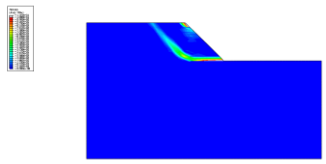
b) Case 2



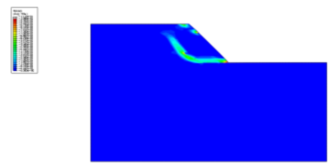
c) Case 3



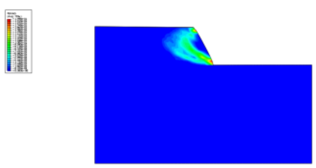
d) Case 4



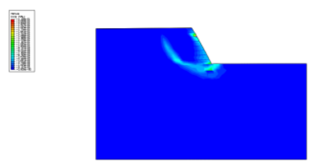
e) Case 5



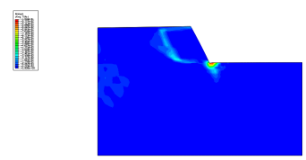
f) Case 6



g) Case 7



h) Case 8

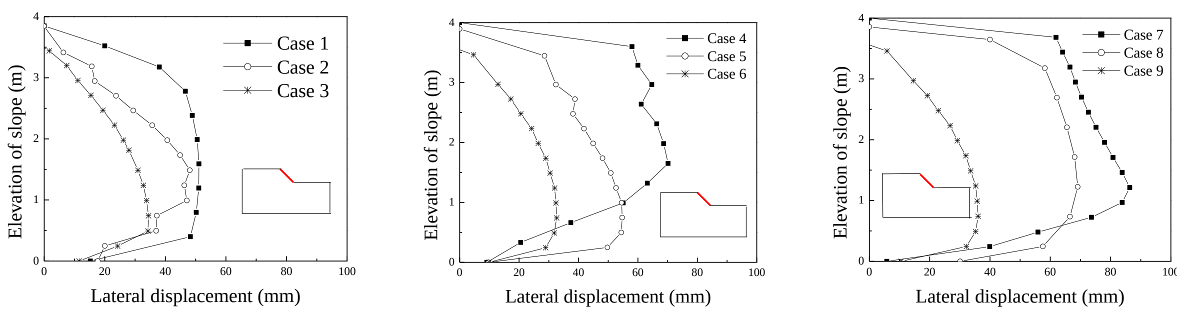


i) Case 9

Fig.2 Plastic point

Fig.3 (a), (b) and (c), respectively, showed the lateral displacement of the slope surface in slope ratio of 1:0.5~1.5 under the displacement load. It showed that the unreinforced slope had a significant lateral displacement under the displacement load, and the reinforcement could restricted the lateral displacement and the influence of the reinforcement with wrapping facing was significant. The Fig.3 (a) showed the Case 1 had obvious displacement change in elevation 3.6m near the top of the slope surface, and had larger lateral displacement occurred from elevation 0.5m to 3.5m in slope surface, the Case 2 and 3 did not had obvious lateral displacement change near the top of the slope surface and reduced rapidly after reached the largest lateral displacement. The Fig.3 (b) showed that the lateral displacement of Case 4, 5 had obvious displacement change in elevation 3.7m and 3.4m of the slope surface, respectively, and with the depth of the slope increased, the lateral displacement increasing gradually and reduced rapidly after reached the largest lateral displacement. However, the lateral displacement of Case 6 did not had obvious change near the slope top than Case 4 and Case 5 due to the wrapping facing. The Fig.3 (c) showed the lateral displacement of Case 7, 8 had obvious displacement change in elevation 3.8m and 3.5m of the slope surface, respectively. Case 7 and Case 9 represented that with the depth of the slope increased, the lateral displacement increasing gradually and reduced rapidly after reached the largest lateral displacement, and Case 8 had a larger lateral displacement from 0.3m to 3.5m in slope surface.

Fig.4 showed that with the ratio of slope increased, the maximal lateral displacement of unreinforced slope and reinforced slope without wrapping facing increasing, respectively. Due to the reinforcement, compared the average maximal lateral displacement of unreinforced slope, the reinforced slope without wrapping facing reduced the 16%. However, the slope ratio didn't had obvious effect on the maximal lateral displacement of reinforced slope with wrapping facing, the range of the maximal lateral displacement is 32~39mm, and compared the average maximal lateral displacement of unreinforced slope, the reinforced slope with wrapping facing reduced the 48.5%. Fig.5 showed that with the ratio of slope increased, the elevation of maximal lateral displacement of unreinforced slope decreasing, but the reinforced slope with wrapping facing was increasing, and reinforced slope without wrapping facing been no influenced by the slope ratio. Due to the reinforcement, compared the average maximal of lateral displacement of unreinforced slope, the reinforced slope without and with wrapping facing was decreasing 19% and 56%, respectively.



a) slope ratio of 1:1.5   b) slope ratio of 1:1.0   c) slope ratio of 1:0.5

Fig.3 lateral displacement of the slopes

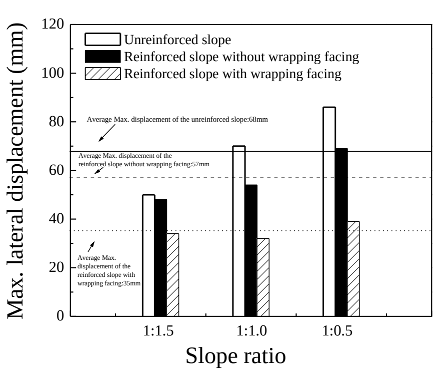


Fig.4 the Max. lateral displacement

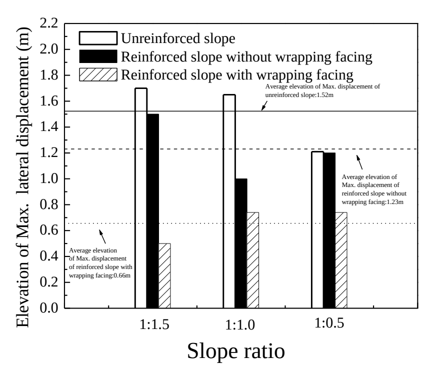
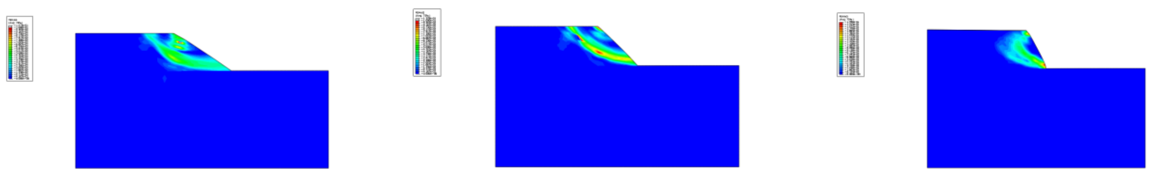


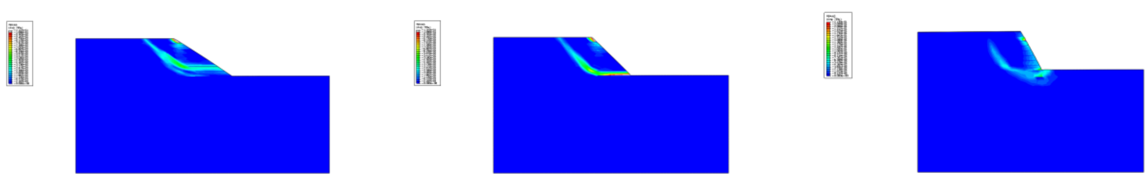
Fig.5 the elevation of Max. lateral displacement

3.2 Influence of the slope ratio

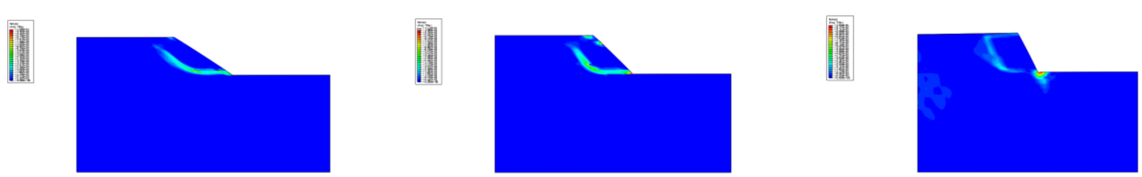
Fig.6 showed the plastic point of the slopes under the displacement load in different slope ratio, with the slope ratio increased, the degree of curvature of plastic point had increasing. The plastic point of unreinforced slope (Case 1, 4 and 7) closed to the slope face with the slope ratio increased. However, the plastic point of reinforcement without wrapping facing slopes(Case 2, 5 and 8) transferred from top to the slope face with the slope ratio increased, and in reinforcement with wrapping facing slopes(Case 3, 6 and 9), the plastic point had appeared in the toe.



a) Case 1 b) Case 4 c) Case 7



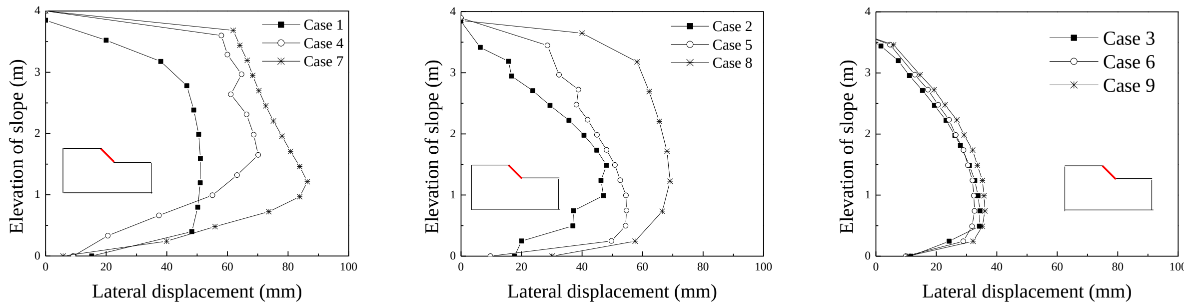
d) Case 2 e) Case 5 f) Case 8



g) Case 3 h) Case 6 i) Case 9

Fig.6 Plastic point

Fig.7 showed the lateral displacement in different slope ratio. Fig.7 (a) and (b) showed that with the slope ratio increased, the largest lateral displacement increasing, respectively. However, the Fig.7 (c) showed that the lateral displacement curves were extremely similar. The results showed that the reinforcement could restrict the lateral displacement of the slope in different slope ratio effectively, and the effect of reinforcement with wrapping facing was significant.



a) unreinforcement slope b) reinforcement without wrapping facing slope c) reinforcement with wrapping facing slope

Fig.7 lateral displacement of the slopes

4. CONCLUSION

A series of numerical simulations on geosynthetics-reinforced soil slopes with and without wrapping facing under displacement load have the following conclusions:

The maximum lateral displacements on the unreinforced soil slope were 119% larger than the reinforced soil slope without wrapping facing, and 194% larger than the reinforced soil slope with wrapping facing. In cases of unreinforced and reinforced soil slope without wrapping facing, the lateral deformation increases as the slope increases. However, in case of reinforced soil slope with wrapping facing, the effects on lateral displacement due to change in slope is negligible. Considering the lateral displacement results, the effects due to reinforcements are remarkable especially on reinforced slopes with wrapping facing.

Based from the plastic point results, there are visible circular arcs developed on the soil slope with the following distinctions: For the unreinforced soil slope, a thick mass of circular arcs were observed and scattered running towards the face of the slope. For the reinforced soil slope without wrapping facing, a thin mass of circular arcs were observed along the end of the reinforcements and a few at the face of the slope. For the reinforced soil slope with wrapping facing, a thin mass of circular arcs were observed along the end of the reinforcements but are negligible at the face of the slope. This may imply that for reinforced soil slope, a block-effect occurred on the soil slope due to the interaction between soil and reinforcement.

The effects of reinforcement on the soil slope were remarkable and more pronounced when the slope became steeper as manifested by the results from the reinforced soil slope with wrapping facing.

5. ACKNOWLEDGEMENTS

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