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PILED EMBANKMENTS FOR ROAD CONSTRUCTION ON SOFT SOIL

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ABSTRACT

Generally, in normal circumstance the thickness of pavements vary from 0.25 to 0.75 m. Therefore, roadway construction is absolutely low on embankment. Besides geosynthetic as a reinforcement with mechanism of membrane effect on bottom of embankment, piles are also vertically installed together to support it. When soft soil is too deep, friction or floating piles can be a good choice, but in this paper we only focus for end-bearing piles or basally reinforcement. Because of difference between soft soil and piles, the arching effect would occur on the surface. This phenomenon was known as soil arching. Some researchers have introduced some theories to explain it. Furthermore, concentration stress ratio resulted from soil arching will be observed using two different geometries of coverage ratio. Afterwards, two different strengths or stiffness of geosynthetics will be compared as well. In this paper the parameters of design will be analyzed by using BS 8006 method and EBGEO method, and verified with Finite Element Method using Plaxis 2-D version of 2010.

Keywords: BS 8006; EBGEO; Finite Element; Floating piles.

1. INTRODUCTION

Two limiting factors restrict engineers when conducting the construction of embankments over soft soil, namely: the presence of the soft soil restricting the geometry. Secondly, characteristics of soft foundation soils are highly compressible and relatively large for consolidating settlements. Various techniques exist to increase the effective shear strength for ground improvement which can be applied to build roadway over soft soil, such as replacement using better material, vertical drain, chemical stabilization, preloading and piled embankments. The use of piles to support embankment on soft soil is a popular technique. The technique which best enables embankments to be constructed to unrestricted heights, with subsequent controlled post-construction settlements, is by piling.

On shallow soft soil, by using pile we can directly construct the roadway (embankments) without waiting for the time of consolidation of soil to the final stage. But, on the contrary situation when embankment is located on deep soft soil, the final settlement of structure depends on time consolidation because of creep.

Some methods or guidances to construct embankment on shallow soft soil using the piling technique and combined with basally reinforcement are so called “geosynthetics supported piled embankments”, such as BS 8006 (1995), EBGEO (2010), Scandinavian Guidline. This method is an environmentally friendlyapproach because it relatively does not disturb any circumstance condition. The Netherland at the end of 2000 develop the guidance for piled embankment by literature review and experimental works (Van Eekelen et al., 2008, 2009).

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The concept of soil arching has been observed by some researchers. Terzaghi (1943) introduced rectangular prism theory. Guido (1987) analysed rectangular pyramid for soil arching. The shape of semicircular arch was introduced by Hewlett&Randolf (1988). In British Standard, it modified the Marston'equation (1913) by using positive projecting subsurface conduit. In EBGEO 2010, the German standard introduced multi vaulted dome to explain the soil arching.
Main goal of the research is to promote the technique of environmentally friendly\ approach when constructing emabankments/ roadway over soft soil.

2. METHODOLOGY/ EXPERIMENT

To compare two methods (BS 8006, 1995 and EBGEO, 2010) in the field, some parameters must be input into 2 cases. And also Finte Element using 2-D plaxis is applied to verify the results of two methods compared.

2.1. Size of datasets

Some input parameters, such as H (height of embankment fill), s (piles spacing), a (width of pile cap), γ (unit weight of embankment material), ϕ (internal friction angle), q (surcharge load) have to be determined to make calculation. Magnitudes of some input parameters are H=0.30 to 1.5 m, γ=18 kN/m^3, ϕ vary from 25^{o,} to 40^o and q (surcharge loads) vary from 0 kPa to 80 kPa. Moreover, maximum strain of geosynthetic (ε_{max}) taken 6 % and two different of elastic moduli of geosynthetics are 270 and 1500 kN/m. Partial factors are taken equal to one for analysis. For finite element method, parameters consist of cohesion of 11.5 kPa and friction angle of 34^O. The hardening soil model is applied for material of embankment.

2.2. Case Study

Here, there are two case for geometry that will be addressed and arranged using square pattern, namely:

Case 1: a = 20 cm (circular pile cap) and s_x or s_y = 50 cm, (coverage ratio of 12.56 %)
Case 2: a = 30 cm (circular pile cap) and s_x or s_y = 127 cm, (coverage ratio of 4.38 %)

Coverage ratio is percentage of pile cross section area to the grid area of four piles inserted vertically in the piled embankments.

3. RESULTS

3.1. Arching Coefficient and Stress Concentration Ratio

By using BS 8006 method for q (surcharge load) are 0 kPa and 80 kPa, the arching coefficient (C_c) for two type of piles and stress concentration ratio (SCR) or ratio of stress on pile caps after arching of soil to overburden stress (p'_c / σ'_v) as presented in Table 1.

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Table 1 Cc and SCR on height of embankment with q= 0 kPa and 80 kPa for two cases

H (m)	Case 1						Case 2					
	End Bearing Pile			Friction Pile			End Bearing Pile			Friction Pile		
	Cc	SCR		Cc	SCR		Cc	SCR		Cc	SCR	
		q = 0	q = 80		q = 0	q = 80		q = 0	q = 80		q = 0	q = 80
0. 30	3.12	3.40	3.40	2.47	2.13	2.13	1.99	3.20	3.20	1.60	2.06	2.06
0. 40	4.23	3.50	3.50	3.32	2.16	2.16	2.71	3.34	3.34	2.15	2.11	2.11
0. 45	4.78	3.53	3.53	3.74	2.17	2.17	3.07	3.39	3.39	2.43	2.13	2.13
0. 60	6.43	3.60	3.60	5.01	2.19	2.19	4.15	3.49	3.49	3.26	2.16	2.16
0. 75	8.08	3.64	3.64	6.29	2.20	2.20	5.24	3.55	3.55	4.10	2.18	2.18
0.90	9.73	3.67	3.67	7.56	2.21	2.21	6.32	3.59	3.59	4.93	2.19	2.19
1.20	13.04	3.70	3.70	10.10	2.22	2.22	8.49	3.65	3.65	6.60	2.20	2.20
1.50	16.34	3.72	3.72	12.64	2.23	2.23	10.65	3.68	3.68	8.26	2.21	2.21

From Table 1, we can see that C_c, P'_c and SCR increase with increasing height of embankment. Moreover, these values (C_c, P'_c and SCR) are independent with increasing q (surcharge load). These values comply with the type of piles which is the highest of SCR value and is end-bearing pile.

EBGEO method includes the soil properties, such as the internal friction angle and cohesion. The effect of internal friction angle on the stress concentration ratio is as presented in Table 2 below.

Table 2 SCR on the height of embankment with q= 0 kPa and 80 kPa and various internal friction angle for 2 cases

H (m)	Case 1						Case 2					
	Stress Concentration Ratio (SCR)						Stress Concentration Ratio (SCR)					
	Surcharge Load		Internal Friction Angle				Surcharge Load		Internal Friction Angle			
	q = 0	q = 80	$q = 25^0$	$q = 30^0$	$q = 35^0$	$q = 40^0$	q = 0	q = 80	$q = 25^0$	$q = 30^0$	$q = 35^0$	$q = 40^0$
0. 30	2.90	2.90	2.45	2.90	3.43	4.04	1.56	1.56	1.41	1.56	1.76	2.00
0. 40	3.61	3.61	3.04	2.61	4.23	4.91	1.97	1.97	1.72	1.97	2.30	2.72
0. 45	3.81	3.81	3.22	3.58	4.45	5.13	2.21	2.21	1.89	2.21	2.61	3.13
0. 60	4.23	4.23	3.59	4.23	4.90	5.57	3.03	3.03	2.50	3.03	3.68	4.51
0. 75	4.48	4.48	3.81	4.48	5.16	5.83	3.95	3.95	3.20	3.95	4.87	6.02
0.90	4.65	4.65	3.96	4.65	5.34	6.00	4.92	4.92	3.94	4.92	6.10	7.54
1.20	4.86	4.86	4.14	4.86	5.56	6.22	6.22	6.22	4.99	6.22	7.65	9.30
1.50	4.98	4.98	4.25	4.98	5.69	6.35	7.00	7.00	5.62	7.00	8.57	10.35

German method of EBGEO 2010 based on end bearing pile takes into account the properties of embankment material (internal friction angle). Stress concentration ratio values for two cases and the effect of internal friction angle on SCR values is as presented in Table 2, and clearly as shown in Figure 1 and 2 below.

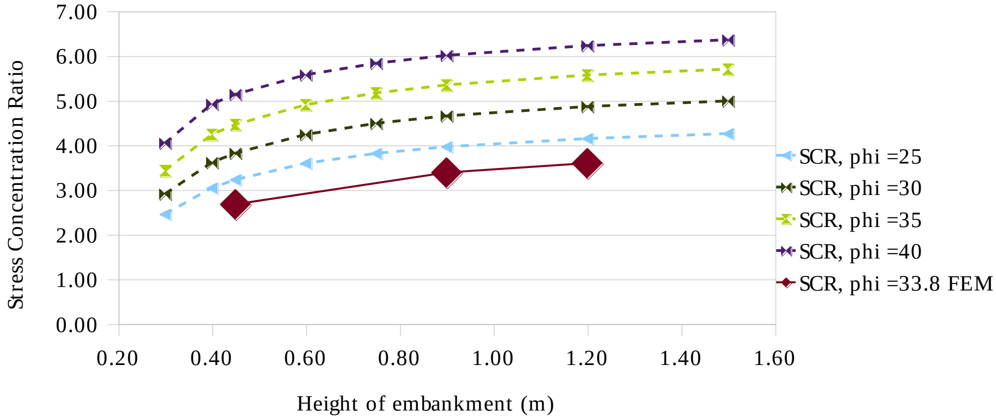

Figure 1. SCR values on variation of height of embankment and internal friction angle at case 1 with coverage ratio of 12.56 %.

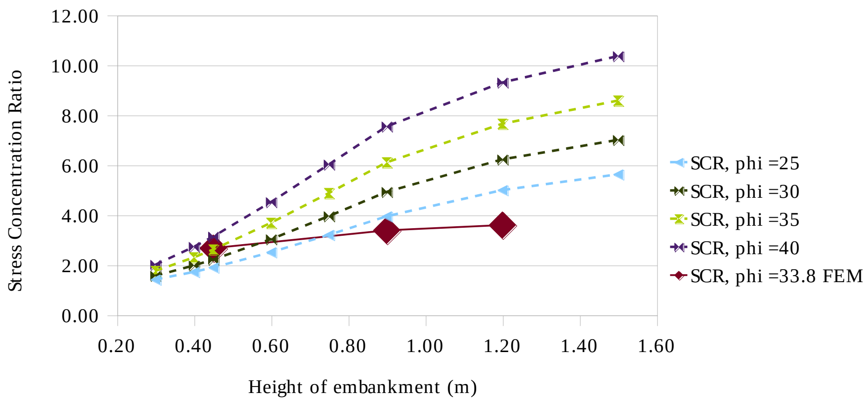

Figure 2. SCR values on variation of height of embankment and internal friction angle at case 2 with coverage ratio of 4.38 %.

The EBGEO method also indicates that higher coverage ratio will result in the higher SCR values for the embankment height of around 40 cm otherwise for the embankment heights more than 40 cm suggest the opposite result. Furthermore, in this method the SCR values are overestimate than those of finite element method. The result of finite element method is close to the result using BS 8006.

3.2. Tensile Forces Acting on Geosynthetics

Geosynthetic resists tensile force from vertical load and horizontal outward thrust of embankment. Tensile force resulted from vertical stress (P_{RP}) and horizontal outward thrust. (P_{RL}). In this paper, calculation was conducted by BS8006 and Modified BS8006 were presented in other to give comparison as shown in Figure 3.As for q (surcharge load) it is equal to zero because surcharge load does not influence tensile force when the full arching is achieved.

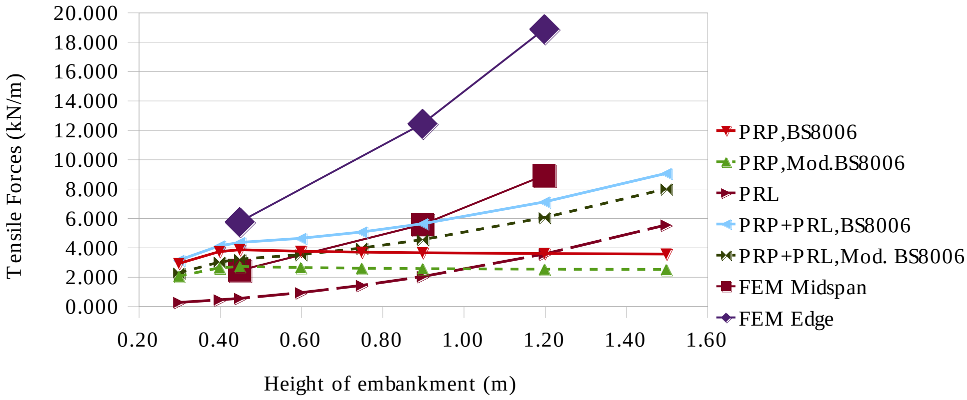

Figure 3. Tensile force from vertical load and horizontal thrust at case 1, q = 0 kPa

Geosynthetics reinforcement to resist tensile forces are resulted from vertical stress (P_{RP}) and horizontal outward thrust (P_{RL}) as depicted in Figure 3. Tensile stress is resulted from horizontal outward thrust which increases with increasing height of embankment. This trend is also similar to tensile force resulted from vertical loading for H less than 1.4 (s-a) but after this point it is not influenced by height of embankment. It means that surcharge load will not affect the tensile force after this point. Compared with Finite Element Method, the tensile forces of geosynthetics using BS 8006 are lower particularly for tensile forces in the edge or proximity zone between piles and geosynthetics layer.

When using EBGEO method with no soil support, surcharge load and stiffness of geosynthetics influence the tensile force of geosynthetic at case 1 as shown in Figure 4. Furthermore, when applying low stiffness of geosynthetic (270 kN/m) and surcharge load of 20 kPa result in strain of geosynthetics of more than 6 % at embankment height of more than 120 cm. In addition, application of higher stiffness of geosynthetics implies higher tensile force of geosynthetic. On the other hand, higher embankment height provides higher tensile force of geosynthetics to resist lateral force. Case 1 with pile spacing of 50 cm and coverage ratio of 12.56 % as shown in Figure 10, and for case 2 having wider pile spacing (127 cm) and coverage ratio of 4.38 % will give the higher tensile force caused by vertical load. Comparison using finite element method for tensile forces in the mid-span and edge of geosynthetics is presented as well.

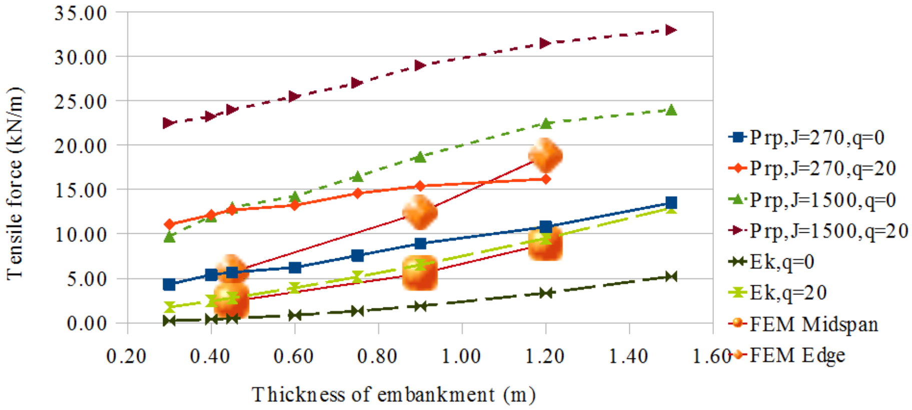

Figure 4. Tensile force from vertical load and horizontal thrust at case 1 for $\phi = 30^o$

4. DISCUSSION

From Figure 1 and 2 regarding with cases 1 and 2 that arching coefficient (Cc), and stress concentration ratio (SCR) will proportionally increase with the height of embankment. But it is not for friction piles. Another result is that the higher friction angle will result in Cc and SCR higher value. It means that the higher friction angle implies the arching effect, which was verified by using FEM.

From Figure 3 and 4, when geosynthetics was inserted on basal reinforcement, the higher embankment will result in the higher tensile force of geosynthetics. The highest tensile force of geosythetics was located on the edge of piles as verified by using FEM. By using it is revealed that BS 8006 of the tensile force was not influenced by the hight of embankment. It is a drawback of this method.

Surcharge on the surface of embankment implies the higher value for Cc, SCR and tensile force of geosynthetics.

5. CONCLUSION

It is worth to note that kind of piles will suggest slightly different stress concentration ratio and that the higher embankment will increase the values of SCR and Cc. However, surcharge load does not affect these values for BS 8006 method, except for EBGEO method. Assumption that higher coverage ratio gives higher stress concentration ratio is not always true, since pile spacing has to be considered as well. Actually the definition for stress concentration ratio (SCR) in this paper is more appropriate as competency ratio or another definition as column stress ratio (CSR). Properties of soil as the internal friction angle will give the higher value of stress concentration ratio for the higher value of friction angle.

According to British Standard BS 8006 that after a critical height of embankment which is more or less 1.4 (s-a) that height of embankment and surcharge load do not influence the tensile force of geosynthetics caused by vertical loading. In addition, application of higher stiffness of geosynthetics in the field will provide higher tensile force of geosynthetics. Other results suggest that by using method of EBGEO we have the safer situation and more realistic value as compared with finite element method, particularly for tensile force of geosynthetics in case of high embankment (height of embankment is more than critical height).

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