Progress in Engineering Application and Technology Vol. 2 No. 1 (2021) 418–424

PEAT

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Settlement Analysis on The Road Embankment with Different Layer Of Geotextile

Wan Mohamad Ammar Wan Kamil[1], Nur Faezah Yahya[1]*, Tuan Noor Hasanah Tuan Ismail[1], Muhamad Faiz Abd Latif[2]

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh, 84600, Johor, MALAYSIA

[2]Department of Transportation Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, Pagoh, 84600, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2021.02.01.041
Received 13 January 2021; Accepted 01 March 2021; Available online 25 June 2021

Abstract: The challenge of road embankment constructions in geotechnical engineering is still unresolved, especially natural soft clay. While the urban areas being more overcrowded, it is very crucial to construct on soft clays. The woven geotextile has been proposed as reinforcement. Full-scale test embankments equipped with geotextile and unreinforced embankments with different loading have been virtually constructed on soft clay site at Chukai, Kemaman. The main purpose of this paper is to analyze the settlement value on number of layer geotextile with different loading on road embankment by using Finite Element Method (FEM). In FEM, Plaxis 2D Connect Edition V8 software was used in simulating real time construction of the embankment. Thus, FEM will be used as back analysis on the determination of parameters that influences the results. The comparison data of settlement value with different application of load will shows the most suitable number of geotextile layer installed.

Keywords: Road Embankment, Soft Clay, Geotextile, Reinforcement, Finite Element Method (FEM), Settlement.

1. Introduction

Recently, the Public Works Department of Malaysia (PWD) had involved in many highway projects on soft soil. Soft soil typically characterized as soil with low shear strength, highly compressible and low permeability [1]. While soft clay is part of soft soil and any structure built on unstable properties of soft clay will be contributing to the significant problem throughout the construction. The high compressibility properties of soft clay are among the significant factors that could lead to a high settlement. The properties of soft clay have very fine particles and high cohesive, especially in water.

*Corresponding author: nurfaezah@uthm.edu.my

The soft clay has the lowest permeability value where water is hard to get through its tiny particles and has a high moisture content [2].

Nowadays, various alternatives are available to increase the strength, stiffness, and improve soil behaviour under various loading and environmental conditions. Geotextiles are the soil reinforcement most widely used in various civil and environmental engineering projects. It is because geotextiles are cost-effective and environment-friendly in soil reinforcement [3]. Besides, various previous studies used geotextile as reinforcement in soft soil embankment. While the geotextile layers increase the embankment stability by virtue of two primary functions, tensile reinforcement and a drainage element reduce pore pressures [4].

1.1 Objective of the study

The objective of this study is to determine the maximum settlement value with a different number layer of geotextile and loading on road embankment. Then, identify the sufficient number of layer geotextile with a minimum value of a settlement.

1.2 Scope of the study

A finite element simulation of a road embankment with geotextile was carried out using Plaxis 2D software in this study. The model was loaded with an axle load increasing from 0 kN to 100 kN with interval 20 kN. The geometry model of road embankment is 3 m height, 16 m wide, and slope inclination for both sides is 1V:2H [5]. The axial stiffness, EA = 2500 kN/m has been used in the model, and the number of the geotextile layers was taken one layer, two layers and three layers in different positions [6].

2. Literature Review

2.1 Geotextile

Geotextiles are synthetic permeable textile materials that are used for improving soil characteristics. The function of geotextiles is as separator, filter, reinforce, protect, and drain when used in the soil. Typically geotextiles are made from polymers such as polyester or polypropylene [7].

2.2 Types of geotextiles used in road reinforcement

A variety of geotextiles are used in road reinforcement applications including wovens and non-wovens. The woven geotextiles are made by interlocking fabric strips that strengthen and stabilise the project where geotextiles are needed. Woven geotextiles are made of polypropylene strips that can withstand a large amount of tension and suitable for separation and reinforcement purposes [8].

The non-woven geotextiles are made from either continuous filament yarn or short-staple fibres. The fibres are usually bonded using thermal, chemical, or mechanical techniques or combining two or all methods. The main function of the non-woven geotextiles is for separation, protection, and filtration purposes in the areas of roadway, railroad, landfill, or civil and environmental projects [8].

3. Methodology

3.1 Geometry Model

The 3 m height of embankments with slopes as 1V:2H as presented in Figure 1. was investigated in this study. The geotextile layers were taken one layer (y_1 = 0 m), two layers (y_1 = 0 m; y_2 = 1.2 m), and three layers (y_1 = 0 m; y_2 = 1.2 m; y_3 = 1.8 m) in different positions and axle load are applied from 0 kN to 100 kN with interval 20 kN.

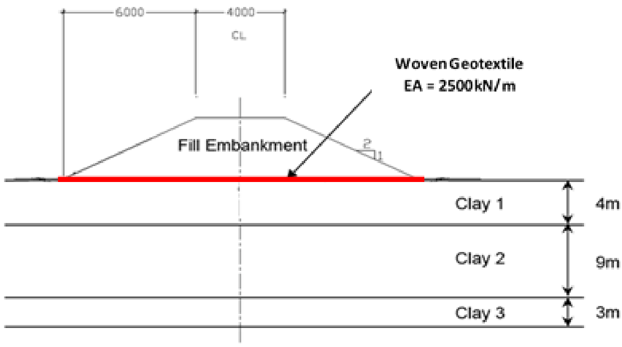

Figure 1: The embankment geometry model

3.2 Properties of Material

The material involved in this studied are fill embankment, clay 1, clay 2, clay 3, and woven geotextile. The fill embankment has been modelled using the Mohr-Coulomb model. The fill material is set for drained and for the foundation layer, it set by undrained behaviour. Other three layer of foundation; clay1, clay 2, and clay 3 were modelled with the Soft Soil Creep model (SSC) provided by Plaxis 2D software. Table 1 and Table 2 show the properties of soil and geotextiles are used to simulate the reinforced road embankment.

Table 1: The soil properties of road embankment

Parameter	Name	Backfill	Clay 1	Clay 2	Clay 3	Unit
General [5]						
Model	-	Mohr-Coulomb	Soft-Soil Creep	Soft-Soil Creep	Soft-Soil Creep	-
Drainage type	-	Drained	Undrained (B)	Undrained (B)	Undrained (B)	-
Dry unit weight	y_{unsat}	16.0	15.0	15.5	15.0	kN/m^3
Bulk unit weight	y_{sat}	18.5	17.5	17.5	18.0	kN/m^3
Parameters						
Modified compression index [5]	λ*	-	0.09	0.055	0.04	-
Modified swelling index [5]	k*	-	0.037	0.025	0.015	-
Friction angle [5]	φ'	25	20	18	30	°
Modified creep modulus [5]	μ*	-	2.14 x 10^{-4}	2.40 x 10^{-4}	1.00 x 10^{-3}	-
Cohesion [5]	c'	8	5	2	15	kN/m^2
Poisson ratio [5]	v'	0.38	-	-	-	-
Dilatancy cut-off [9]	-	No	No	No	No	-
Void ratio [9]	e_{init}	0.5	0.5	0.5	0.5	-
Young Modulus [5]	E	8500	-	-	-	kN/m^2
Undrained behaviour [9]	-	Standard	Standard	Standard	Standard	-

Table 2: The properties of reinforced materials

Material	Model type	Material type	EA (kN/m)
Woven Geotextile	Geogrids [5]	Elastic [5]	2500 [6]

3.3 Method to Analysis

The axle load are applied from 0 kN to 100 kN with lay the geotextile layers as one layer (y_1 = 0 m), two layers (y_1 = 0 m; y_2 = 1.2 m), and three layers (y_1 = 0 m; y_2 = 1.2 m; y_3 = 1.8 m) in different positions. The modelling was applied fine meshes, and the construction phase applied based on previous research data [5] as per showed in Table 3.

Table 3: Construction phase of the embankment [5]

Phase	Description	Thickness (m)	Duration (Days)
1	First layer	0.0-0.9	1
2	Second layer	0.9-1.2	6
3	Third layer	1.2-1.5	1
4	Fourth layer	1.5-1.8	1
5	Fifth layer	1.8-2.1	1
6	Sixth layer	2.1-2.4	3
7	Seventh layer	2.4-2.7	3
8	Eighth layer	2.7-2.97	1
9	Consolidation	-	401
10	Loading	-	1

4. Results and Discussion

This section presents the Plaxis 2D software results with prediction settlement value on the different loading and number of layer geotextiles. The comparison is very important to evaluate which are the most suitable number of layer geotextile with minimum value of settlement. Figures 2 to 7 illustrated the maximum settlement value on the road embankment under various loads applied with a different geotextile number.

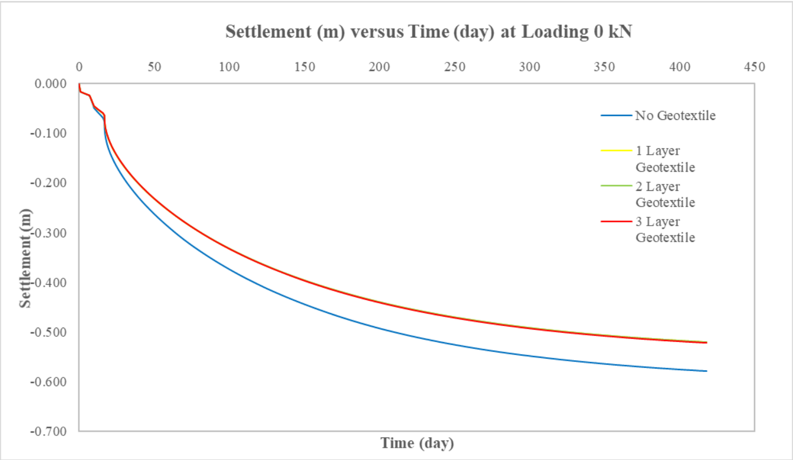

Figure 2: Settlement value on a different number of the layer at loading 0 kN

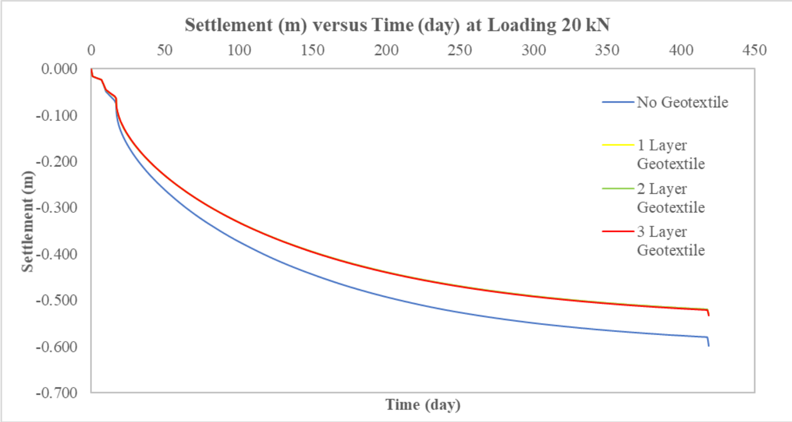

Figure 3: Settlement value on a different number of the layer at loading 20 kN

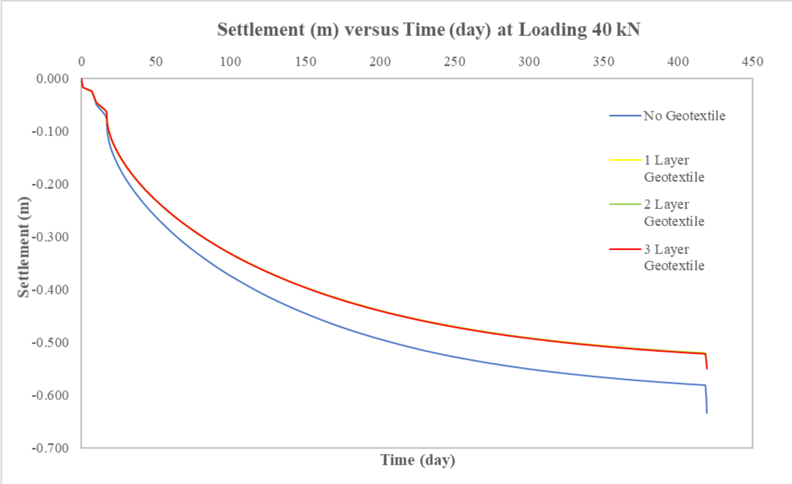

Figure 4: Settlement value on a different number of the layer at loading 40 kN

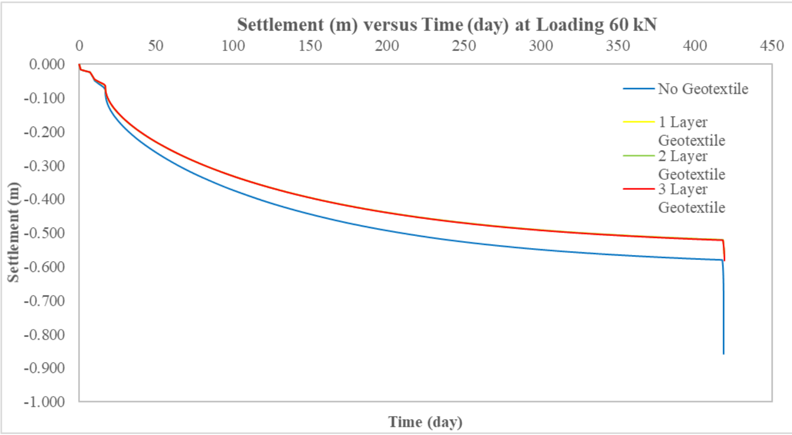

Figure 5: Settlement value on a different number of the layer at loading 60 kN

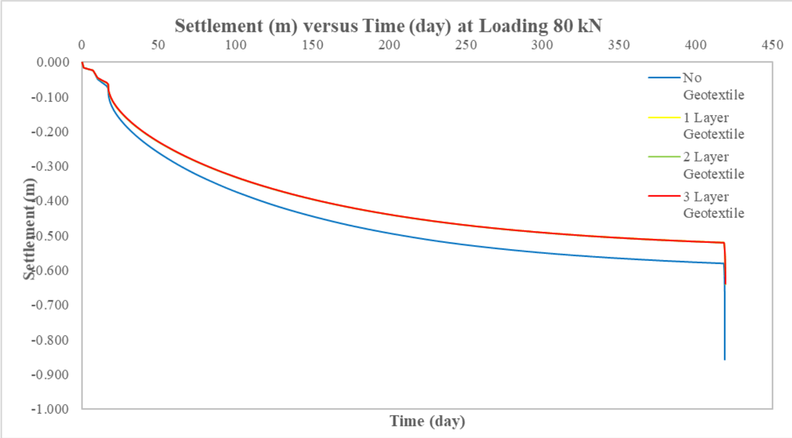

Figure 6: Settlement value on a different number of the layer at loading 80 kN

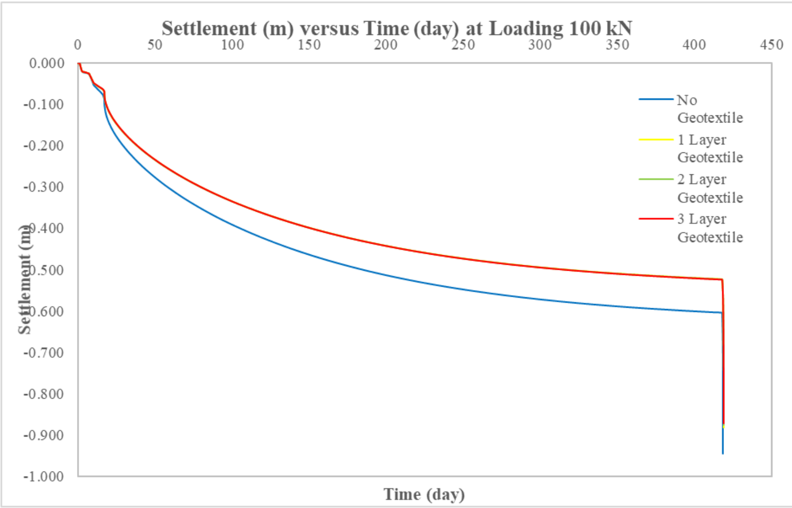

Figure 7: Settlement value on a different number of the layer at loading 100 kN

According to Figure 2 to 7, the result shows that the settlement value on the three-layer of geotextile is not immense different from the one-layer of geotextile. Then, the settlement value increased when increasing the road embankment load as per shown in Table 4. Table 4 summarises of maximum settlement value with the number of layer geotextiles at every loading applied. In summary, one-layer geotextile is enough to use rather than three-layer to minimize the settlement value on-road embankment. The settlement value between one-layer and three-layer are not too different, as illustrated in Figure 2 to 7 and Table 4.

Table 4: The settlement value for each loading applied on the embankment

Loading (kN)	Maximum Settlement (m)			
	No Geotextile	1 Layer Geotextile (y1 = 0 m)	2 Layer Geotextile (y1 = 0 m; y2 = 1.200 m)	3 Layer Geotextile (y1 = 0 m; y2 = 1.200 m; y3 = 1.800 m)
0	-0.579	-0.521	-0.521	-0.522
20	-0.600	-0.532	-0.532	-0.533
40	-0.634	-0.549	-0.549	-0.550
60	-0.859	-0.580	-0.580	-0.582
80	-0.858	-0.641	-0.641	-0.639
100	-0.945	-0.883	-0.877	-0.873

5. Conclusion

In this study, the loading, location and number of layer geotextiles tend to increase settlement value. In this paper, using FEM analysis shows that the close results with the observed results. It proved that the software's accuracy using FEM to predict the settlement using the right constitutive model used. Although the geotextile application minimises settlement value and the geotextile EA value is insufficient. The geotextile needs a higher value of EA to reduce the settlement value. It is almost impossible to prevent any settlement on soft clay soil. The Plaxis 2D software could be more friendly users to solve another problem related to the behaviour of materials such as bamboo can be a float, and some geotextile could act as good drained materials [5].

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, for its support.

References

[1] N. O. Mohamad, C. E. Razali, A. A. A. Hadi, P. P. Som, B. C. Eng, M. B. Rusli, and F. R. Mohamad, “Challenges in construction over soft soil – case studies in Malaysia,” in Materials Science and Engineering: Soft Soil Engineering International Conference 2015 (SEIC2015), July 2016, doi: 0.1088/1757-899X/136/1/012002

[2] Q. A. Aljanabi, Z. Chik, and A. Kasa, “Construction of a new highway embankment on the soft clay soil treatment by stone columns in Malaysia,” Journal of Engineering Science and Technology, vol. 8. no. 4, pp. 448 – 456, 2013.

[3] N. S. Parihar, R. P. Shukla, and A. K. Gupta, “Effect of reinforcement on soil,” International Journal of Applied Engineering Research, vol. 10, no.55, pp. 4147-4151, June 2015.

[4] I. K. Ankita, G. Devika, K. Lakshmi Priya, R. Remya, and J. Jayamohan, “Applications of Geosynthetics in Embankments- A Review,” International Advanced Research Journal in Science, Engineering and Technology, vol. 5, no. 1, pp. 31 – 41, Feb. 2016, doi: 10.17148/IARJSET.

[5] A. Marto, F. Kasim, and B. A. Othman, “Numerical analysis of bamboo-geotextile composite reinforced embankment on soft clay,” International Conference on Advances in Geotechnical Engineering 2011, Nov. 2011.

[6] P. Majedi, B. K. Ghalehjough, S. Akbulut, and S. Çelik, “Effect of reinforcement on stability and settlement of embankment: a finite element analysis of different kinds of reinforcing and construction conditions,” European Journal of Advances in Engineering and Technology, vol. 4, no. 10, pp. 759-764, 2017.

[7] H. Wu, C. Yao, C. Li, M. Miao, Y. Zhong, Y. Lu, and T. Liu, “Review of application and innovation of geotextiles in geotechnical engineering”, MDPI in Journal of Materials Science and Engineering, vo. 13, no. 7, pp. 1774, 10 April 2020.

[8] R. M. Koerner. Geotextiles from Design to Applications, Matthew Deans, 2016.

[9] Tutorial Manual, Plaxis 2D Manuals.

[10] F. Kasim, A. Marto, B. A. Othman, I. Bakar, and M. F. Othman, “Simulation of safe height embankment on soft ground using Plaxis,” vol. 5, pp. 152-156. 2013.