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Analyzing Geotextile as Reinforcement on Road Embankment

Muhammad Zariq Imran Razali[1], **Nur Faezah Yahya**[1]*, **Tuan Noor Hasanah Tuan Ismail**[1], **Muhammad Faiz Abd Latif**[2]

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

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

*Corresponding Author Designation

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Abstract: Construction of soil embankment on soft soil will cause many problems such as big and non-uniform settlement because of soft soil has less shear strength and high compressibility. Nowadays, soil reinforcement is one of the efficient way for increasing the soil strength and stability of the soil. The usage of geo-synthetics specifically geotextile has increasing in demand for recent years that can cause decrease of tensile weaknesses and decreasing the settlement of it. The aim of this research to analyze different loading at different location of geotextile on road embankment by using Plaxis 2D software, to determine maximum value of settlement value of different location of geotextile on road embankment, to identify the location of geotextile to place on the road embankment. In FEM, the 2D PLAXIS software was used in simulating real time of the construction of the embankments starting from distribution of filling work until end of surveillance monitoring data period. In this paper, bottom (y=0.000 m) has minimum value of settlement and was the best location for applying geotextile on the road embankment rather than middle (y=1.200 m) and top (1.800 m).

Keywords: Soft soil, Road Embankment, Plaxis 2D, Geotextile

1. Introduction

Soil is known as material that can bear pressure and shear loads but is not stable in front of tensile loads. Reinforcing soil is one of effective and trustable method for improving and treatment of soil properties. Soils reinforcements are composite materials include elements that can bear tensile loads. Soil reinforcement are used at different issues such as earth dams, slopes or retaining walls and even on stabilization of soil layers under shallow foundation or embankments of roads. The soft soil has created

*Corresponding author: nurfaezah@uthm.edu.my

a challenge to the construction industry, particularly in road construction. The characteristic of soft soil is high compressibility, low shear strength, and low permeability. General construction problems in this deposit are insufficient bearing capacity, excessive post-construction settlement, and instability on excavation and embankment forming. To reduce this general construction on road embankment problem, soil improvement needs to be done [1].

Geosynthetics reinforcement have special rule on increasing of safety factor of slopes. Geosynthetics reinforcements have been divided to groups of geo-membranes, geo-textiles, geo-grids, geo-nets and geo-composites. Because of increasing traffic at recent years, many of road embankments have been made on soft soils. At these conditions engineer has been faced with different problems such as settlement and instability of slopes, so lots of studies have been done on geotextiles as a trustable material for reinforcing and improving soil properties [1].

This project is focused on geotextile that apply on the road embankment. Therefore, this research will cover the scope on the problem issues such as the problem on the road construction on soft soil. Settlement on the road embankment problem due to the stresses applied can be described as a deformation of the soil. The type of geotextile used for this project is woven geotextile that acts as reinforcement to prevent lateral movement of the soil on the road embankment. The model of the road embankment was model by using Finite Element Method (FEM) which is Plaxis 2D.

1.1 Problem Statement

There are two types of pavements, which are flexible pavement and rigid pavement. In Malaysia, flexible pavement is the most common type of road used. Flexible pavement consists of different layers such as subgrade, sub-base course, base course, and surface course. The construction problems caused by soft soil are insufficient bearing capacity, excessive post-construction settlement, and instability on excavation and embankment forming. The settlement problem in soft soil can be defined as a deformation in the soil due to the applied stresses.

1.2 Objectives

The aim of this research to analyze different loading at different location of geotextile on road embankment by using Plaxis 2D software, to determine maximum value of settlement value of different location of geotextile on road embankment, to identify the location of geotextile to place on the road embankment.

2. Literature Review

2.1 Road Embankment

In road construction, the embankment is used to increase the height of the road compared to the height of the surrounding area. The construction involves two essential construction components namely fill and foundation. The embankment foundation containing soft grounds is often a challenge for all engineers to ensure stability depending on the nature of the soil. Soft ground with fine particles such as silt, clay, and peat have high moisture content and are located near or below the groundwater level. These soils also have the characteristics of high compressibility, high plasticity, high sensitivity, low shear strength, and low permeability. Such features will lead to the problem of high settlement and low bearing capacity during post construction work [2].

2.2 Geotextile

Geotextile also has been defined as any permeable textile material used for filtration, drainage, separation, reinforcement and stabilisation purposes as an integral part of civil engineering structures of earth, rock or other constructional materials [3]. There are two types of geotextile which is woven and nonwoven structures that are commonly used in numerous geo-engineering applications.

Nonwovens are mainly used for drainage, lining systems and asphalt overlay fabrics while the woven are frequently used for subgrade and base reinforcement, soil stabilization and separation, and sediment walls [4]. The main function of geotextile is reinforcement that acts to prevent lateral movement of the soil. If a tensile inclusion which is geotextile is added to the soil and forms an intimate contact with it, a composite material can be formed which has superior mechanical characteristics in comparison to the soil alone. During tensile loading, these two materials must experience the same extension as the reinforcing elements redistribute the internal confining stress to the soil [5].

3. Methodology

In order to properly develop a geometry model for the embankment of geotextile reinforced, the methodology section is important to guide student with the best solution. In this methodology part, the geometry model has been designed by using Plaxis 2D software by inserting project properties, soil properties and reinforcement properties by referring to previous research data. Figure 1 illustrates the geometry model of embankment in the previous research data.

3.1 Geometry model

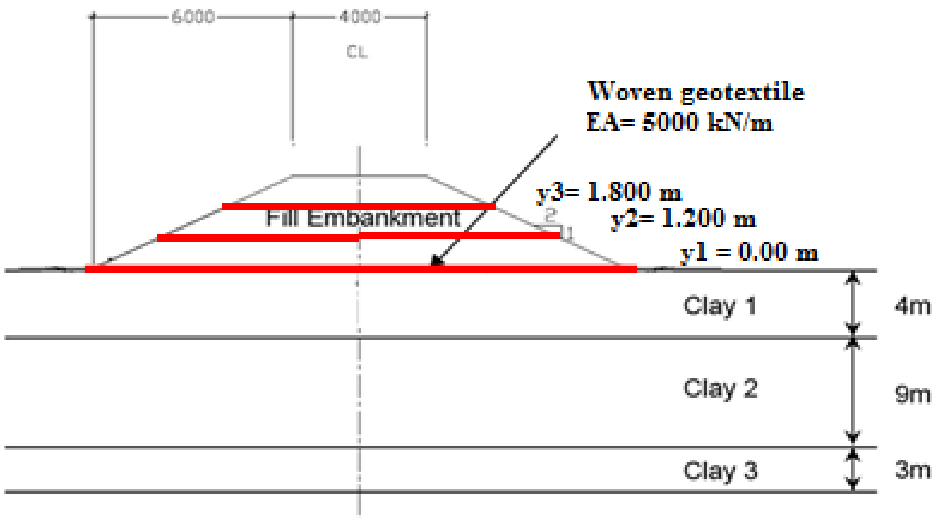

Figure 1: Geometry model of embankment

The model of embankment as per shown in Figure 1 in the research data which are 3 m height, 16 m wide with 10 m long and the slopes inclination for both sides is 1V:2H. The model consists of 3 different locations which are top, middle and bottom of geotextile with a height of 1.8 m, 1.2 m and 0 m respectively. In order to achieve the purpose of this study which is to know the maximum value of settlement of different location of geotextile, 5 different loading was applied into the model which is 0 kN/m^2, 25 kN/m^2, 50 kN/m^2, 75 kN/m^2 and 100 kN/m^2.

Analyses using PLAXIS 2D version 8 software was conduct to analyze the maximum and minimum value of different location of geotextile with 5 different of value of loading on road embankment. Soft soil creep model (SSCM), which considered creep condition had been used to model the foundation soil. The geometry model of the embankment for finite element analysis was half of the actual embankment due to the symmetrical condition of the embankment. Elastic-plastic model with Mohr-Coulomb failure criterion had been applied for the backfill material. The model was analyzed using two-dimensional plain strain model using 6-node of elements for both foundation soil and fill embankments.

Table 1 shows the soil parameters that used in simulation analyses for the road embankment by referring to research paper.

Table 1: The soil properties used in simulation analyses for the embankment

Parameter	Name	Backfill	Clay 1	Clay 2	Clay 3	Unit
General						
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	$\lambda*$	-	0.09 [6]	0.055 [6]	0.04 [6]	-
Modified swelling index	$\kappa*$	-	0.037 [6]	0.025 [6]	0.015 [6]	-
Friction angle	φ’	25 [6]	20 [6]	18 [6]	30 [6]	°
Modified creep modulus	μ*	-	2.14×10^{-4} [5]	2.40×10^{-4} [5]	1.00×10^{-3} [5]	-
Cohesion	c’	8 [6]	5 [6]	2 [6]	15 [6]	kN/m^2
Poisson ratio	v’	0.38 [6]	-	-	-	-
Dilatancy cut-off	-	No [7]	No [7]	No [7]	No [7]	-
Void ratio	e_{init}	0.5 [7]	0.5 [7]	0.5 [7]	0.5 [7]	-
Young Modulus	E	8500 [6]	-	-	-	kN/m^2
Undrained behaviour	-	Standard [7]	Standard [7]	Standard [7]	Standard [7]	-
Groundwater						
Data set	-	-	USDA [7]	USDA [7]	USDA [7]	-
Model	-	-	Van Genuchten [7]	Van Genuchten [7]	Van Genuchten [7]	-
Soil type	-	Sand [6]	Clay [6]	Clay [6]	Silty Clay [6]	-
< 2μm	-	4.00 [7]	70.00 [7]	70.00 [7]	48.00 [7]	%
2μm − 50μm	-	4.00 [7]	13.00 [7]	13.00 [7]	45.00 [7]	%
50μm − 2mm	-	92.00 [7]	17.00 [7]	17.00 [7]	7.00 [7]	%
Use default	-	None [7]	None [7]	None [7]	None [7]	-
Horizontal permeability	k_x	2 [6]	4×10^{-4} [6]	4×10^{-3} [6]	5.5×10^{-2} [6]	m/d
Vertical permeability	k_y	1 [6]	2×10^{-4} [6]	2×10^{-3} [6]	2.7×10^{-2} [6]	m/d

Table 2 illustrates the parameter for the reinforced material that used in simulation the model of road embankment by referring to previous research data.

Table 2: The parameters for reinforced materials

Material	**Model type**	**Material type**	**EA (kN/m)**
Geotextile [1]	Geogrids [1]	Elastic [1]	5000 [1]

3.2 Model analysis

Based on the Table 1 and Table 2, the parameters had been identified to analyze the settlement of the geotextile with different value of loading of road embankment by Plaxis 2D software. The stiffness value of loading that used to analyze the road embankment is 0 kN, 25 kN, 50 kN, 75 kN and 100 kN with interval of 25 kN. The value of axial stiffness geotextile that used in this model road embankment is 5000 kN/m which is suitable for withstand the value of load apply. There are 3 location of geotextile that need to be analyze which is top (y = 1.800 m), middle (y = 1.200 m) and bottom (y = 0.00 m). Aim of this paper is to identify the best location of the geotextile which have the minimum settlement on road embankment with different values of loading.

Table 3 illustrates the construction phase of embankment that used in simulation the road embankment in Plaxis 2D by referring to previous research study.

Table 3: The construction phase of the embankment [6]

Phase	Description	Thickness (mm)	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

The results and discussion section presents data and analysis of the study by using finite element method (FEM) which is Plaxis 2D software. This result and discussion part will present the best location of geotextile with 5 different values of loading and determine the minimum value of settlement on the road embankment. The various stiffness values of loading were used in this paper with interval of 25 kN which is 0 kN, 25 kN, 50 kN, 75 kN and 100 kN. There are 3 location of geotextile that has been analysed in this paper which is bottom (y=0.00 m), middle (y=1.200 m) and top (y=1.800 m).

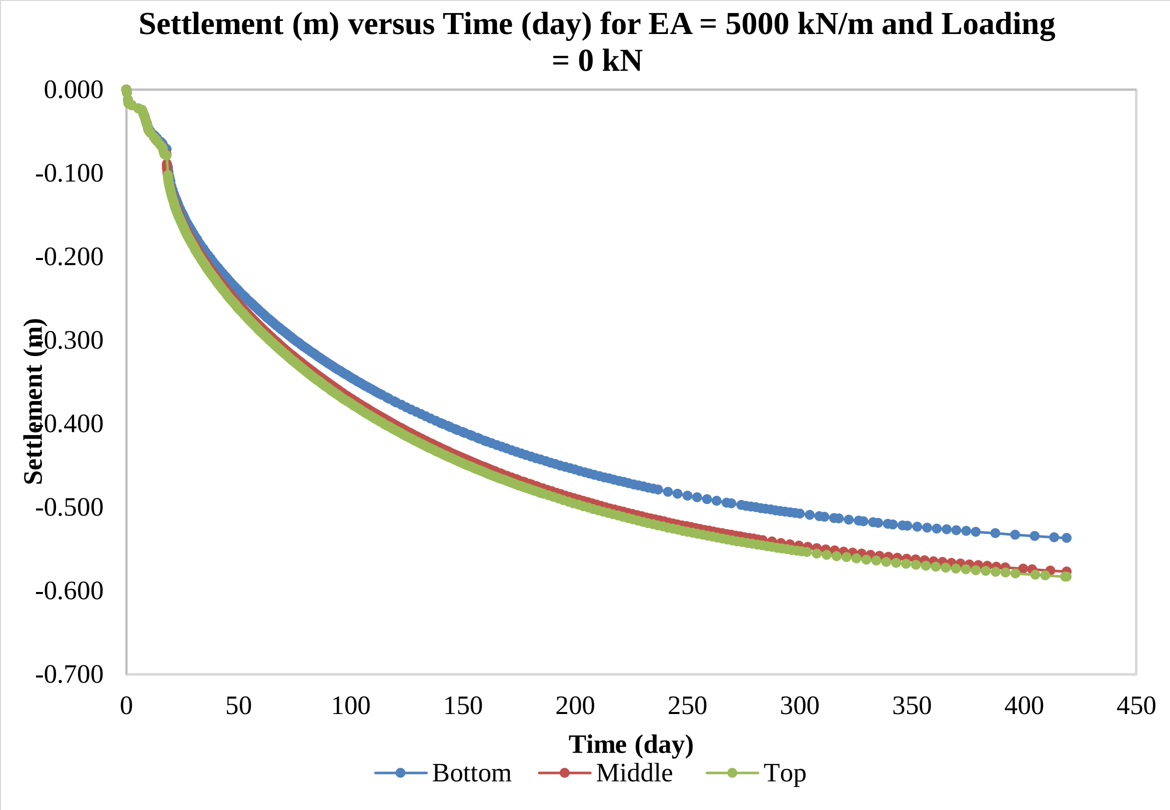

Figure 2: The different location of geotextile with 0 kN

Based on the Figure 2, it shows the graph for different location of geotextile which is bottom (y=0.000 m), middle (y=1.200 m) and top (y= 1.800 m) with a loading of 0 kN and axial stiffness of 5000 kN/m. The graph represents the settlement (m) which is y-axis versus time (day) which is x-axis.

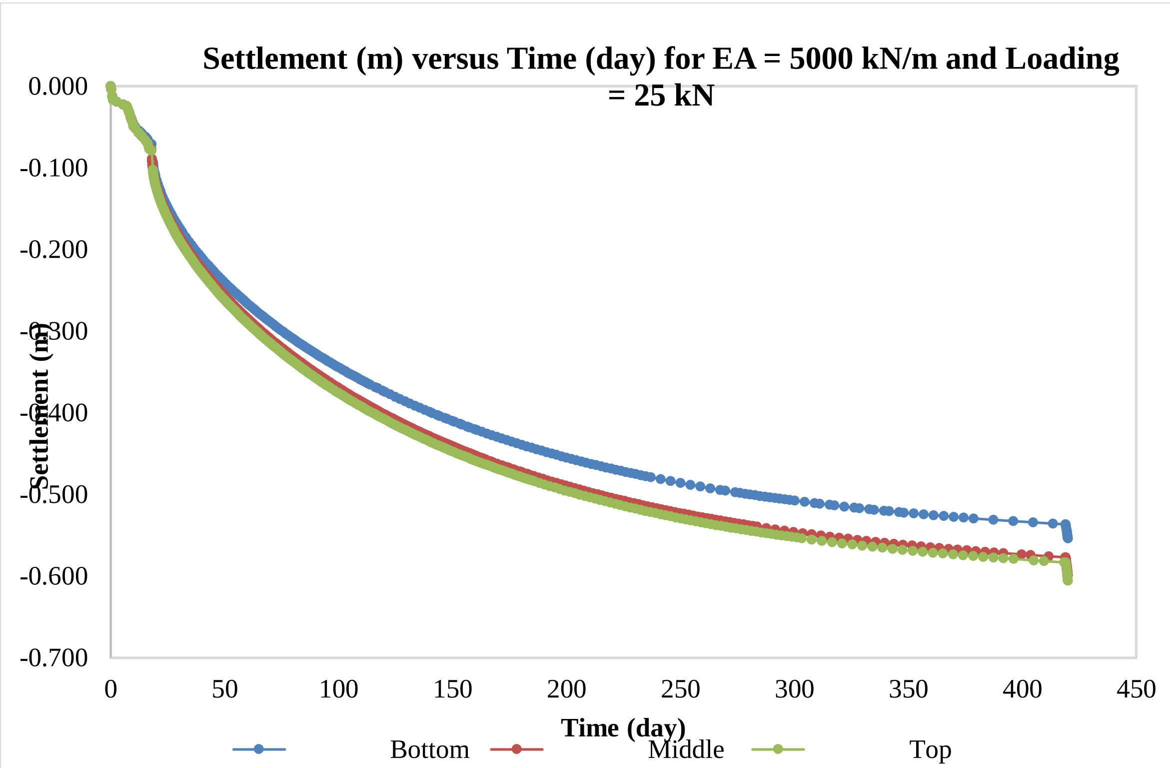

Figure 3: The different location of geotextile with 25 kN

Based on the Figure 3, it shows the graph for different location of geotextile which is bottom (y=0.000 m), middle (y=1.200 m) and top (y= 1.800 m) with a loading of 25 kN and axial stiffness of 5000 kN/m. The graph represents the settlement (m) which is y-axis versus time (day) which is x-axis.

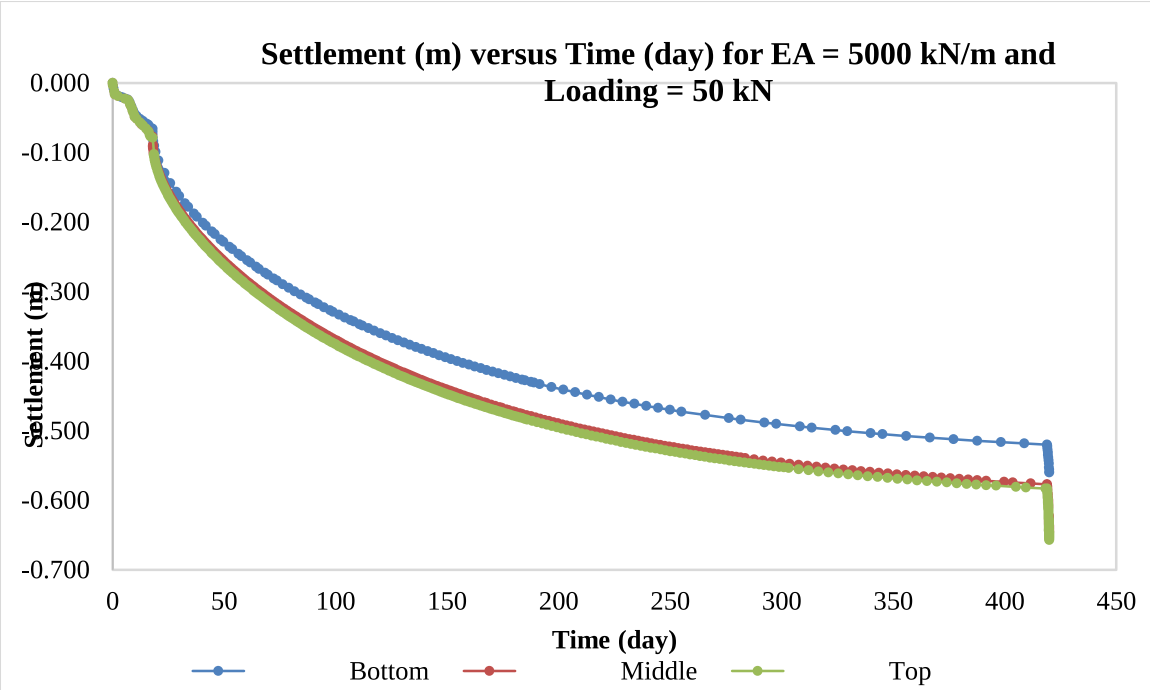

Figure 4: The different location of geotextile with 50 kN

Based on the Figure 4, it shows the graph for different location of geotextile which is bottom (y=0.000 m), middle (y=1.200 m) and top (y= 1.800 m) with a loading of 50 kN and axial stiffness of 5000 kN/m. The graph represents the settlement (m) which is y-axis versus time (day) which is x-axis.

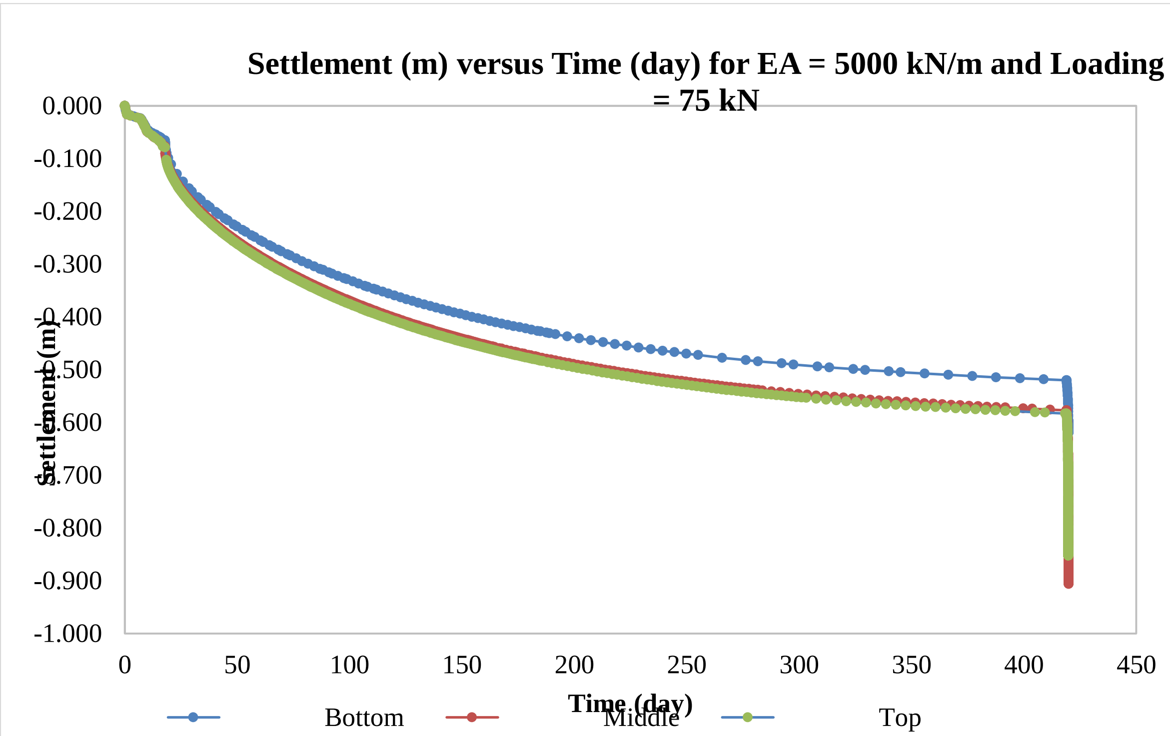

Figure 5: The different location geotextile with 75 kN

Based on the Figure 5, it shows the graph for different location of geotextile which is bottom (y=0.000 m), middle (y=1.200 m) and top (y= 1.800 m) with a loading of 75 kN and axial stiffness of 5000 kN/m. The graph represents the settlement (m) which is y-axis versus time (day) which is x-axis.

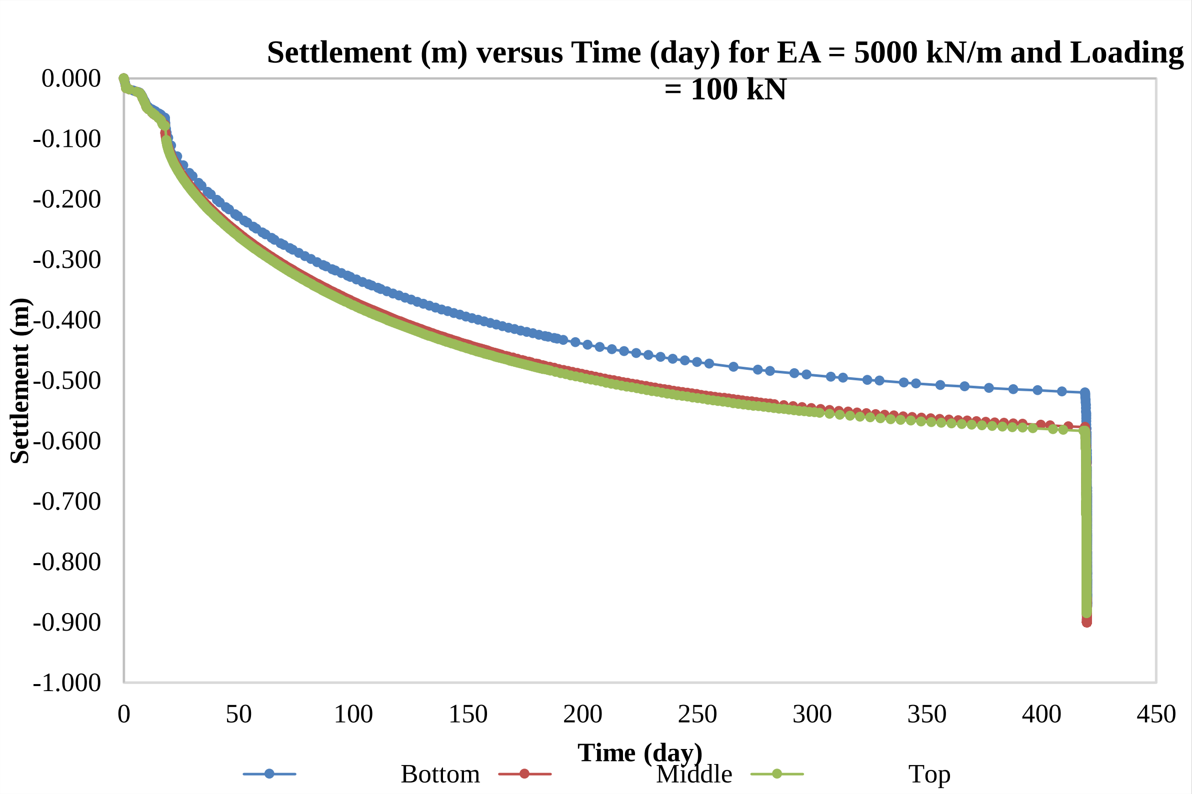

Figure 6: The different location of geotextile with 100 kN

Based on the Figure 6, it shows the graph for different location of geotextile which is bottom (y=0.000 m), middle (y=1.200 m) and top (y= 1.800 m) with a loading of 100 kN and axial stiffness of 5000 kN/m. The graph represents the settlement (m) which is y-axis versus time (day) which is x-axis.

As conclusion on all the graphs above, it shows the different location geotextile with 5 different values of loading which are 0 kN, 25 kN, 50 kN, 75 kN and 100 kN. The value of loading is from 0-100 kN with interval of 25 kN. All the graph and data has been analyses by using Plaxis 2D software.

Table 4 shows the maximum settlement for different location of geotextile with different values of stiffness loading. The location of geotextile that used to in simulation on the road embankment is bottom (y=0.00 m), middle (y=1.200 m) and top (y=1.800 m).

Table 4: The maximum settlement for different location of geotextile and different value of loading

Loading (kN)	Maximum Settlement (m)		
	Bottom (y = 0.00 m)	Middle (y = 1.200 m)	Top (y = 1.800 m)
0	-0.536	-0.577	-0.583
25	-0.554	-0.599	-0.605
50	-0.560	-0.646	-0.657
75	-0.620	-0.906	-0.852
100	-0.874	-0.901	-0.885

The maximum settlement for different location of geotextile with 5 different values of loading as per shown in Table 4. From the table, the location of geotextile which is bottom (y=0.00 m) has minimum settlement rather than the location geotextile which is middle (y=1.200 m) and top (1.800 m). This result shows the proof that bottom has been the best location rather than middle and top by applying different values of loading which is 0 kN, 25 kN, 50 kN, 75 kN and 100 kN. By considering the result, it can conclude that bottom (y=0.00 m) is the best location in order to applying a geotextile on the road embankment.

5. Conclusion

In conclusion, by using Finite Element Method (FEM) which is Plaxis 2D software has the ability of accuracy in order to predict the value of settlement of road embankment. Plaxis 2D is a powerful and user-friendly finite-element package intended for 2D analyses of deformation and stability in geotechnical engineering and rock mechanic. The above analysis shows that geotextile that act as reinforcement on embankment of soft soil could be used to decrease the settlement of soft soil. From the result and table above shows that bottom (y=0.00 m) was the best location for applying the geotextile on road embankment due to the minimum settlement for bottom rather than the others which is middle (y=1.200 m) and (y=1.800 m). For recommendation, the value of axial stiffness (EA) of geotextile should higher in order to reduce or minimize the settlement on the road embankment. Hence, the value of settlement in every location of geotextile could be reduce more than the actual result. In this conclusion, it can be analyze different loading and location of geotextile on road embankment by using Plaxis 2D.

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