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Modelling of Road Embankment on Soft Soil with Geogrid as Soil Reinforcement

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Abstract: As the population of people in this country increasing, the number of road user also increasing. The road network plays a major role in the development of the country. Often these roads are constructed on weak structure of soil such as soft soil. Hence, this paper use geogrid as the soil improvement. The purpose of this paper is to determine the maximum value of settlement at different location of geogrid with different type of geogrid in the road embankment. Next, to compare the maximum value of settlement with different type of geogrid. Lastly, to determine the type of material with minimum value of settlement. This research use 2D plaxis software to analyze the settlement of soil. As conclusion, the lowest location of geogrid is the best location and the geogrid that is made from polypropylene is the best material and the strongest to withstand the load and minimize the settlement.

Keywords: Geogrid, Plaxis 2D, Soil Reinforcement, Road Embankment, Settlement

1. Introduction

Soil improvement is a system that related with the structure of ground to transfer or support loads. It fixes the problems for soft soil such as clay by increasing the strength and reduce the permeability [1]. In this paper, geogrid is being used as soil reinforcement and also as the initiative to improve the performances of road embankment on soft soil. Plus, it is used to support the load from the vehicles on the road embankment and also the load from the soil itself.

Soft soil typically characterized as a soil with low shear strength, highly compressible and low permeability. Plus, over load from heavy vehicles can cause the structure of soil becomes weak and

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cause damage that ease the road embankment to settled [7]. Hence, by this research the road damage will be solved by proposing geogrid in the road embankment layer as soil reinforcement

1.1 Objective of the study

The purpose of this paper is to determine the maximum value of settlement at different location of geogrid with different type of geogrid in the road embankment. Next, to compare the maximum value of settlement with different type of geogrid. Lastly, to determine the type of material with minimum value of settlement.

1.2 Scope of the study

This project is focusing on three geogrid material that is made from polypropylene, HDPE and woven material. Plus, this research was set up using 3-meter height of road embankment and using previous data as benchmarks to predict modelling. Other than that, this paper is using plaxis 2D software to run a finite element simulation of a road embankment with geogrid. The geometry model of road embankment is 3 m height, 16 m wide, and slope inclination for both sides is 1V:2H [1].

The model has been applied an axle load of 100 kN. 3 different types of geogrid being laid in the road embankment which have different axial stiffness value with an increasing of 3 different intervals which is 0 m, 1.200 m and 1.800 m from the bottom layer of the road embankment. Each geogrid were made from different material. The first material with 300 kN/m value of axial stiffness were made from polypropylene [5]. The second geogrid with 2000 kN/m value of axial stiffness were made from woven materials [6]. The last geogrid with 2454 kN/m axial stiffness value were made from HDPE materials [3].

2. Literature Review

Soft clays were a type of fine-grained soils which change volume when different from elastic deformation, consolidation and secondary compression. Besides, soft clay also defined as soils with large fractions of fine particles such as silty and clayey soils, which have high moisture content, peat foundations and loose sand deposits, located near or under the water table [7].

2.1 Road Embankment on Soft Soil

In road construction, the embankment is used to increase the height of the road compared to the height of the surrounding area. It is a large earth structure and is often used in civil engineering applications related to infrastructure projects [1]. The construction involves two essential construction components namely fill and foundation.

2.2 Geogrid

Generally, geogrids are manufactured from polymers like polypropylene, polyethylene or polyester. The strength of geogrids primarily depends on the material from which they are manufactured. Most commonly, high-density polypropylene geogrids of desired shape and structure are used in the structural application. The grid formation is made by punching holes in the required pattern. Those holes are called as apertures. In the process of knitting or weaving, polyethylene or polyester materials are used to form flexible geogrids.

In this paper, three different materials of geogrid being used. The first geogrid is made from polypropylene which its axial stiffness is 300 kN/m. the second geogrid is made from woven which its axial stiffness is 2000 kN/m while the third geogrid is made from HDPE substances which its axial stiffness is 2454 kN/m. figure 1 shows the example of polypropylene geogrid that being used in this research.

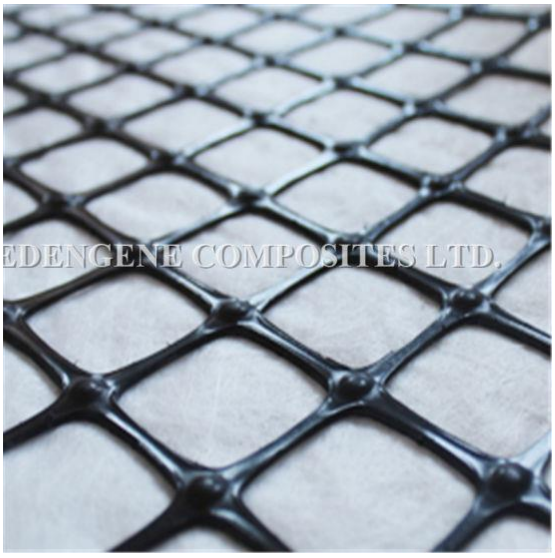

Figure 1: Polypropylene geogrid

3. Methodology

In this research, plaxis 2D are used to analyze the effects of settlement value with the presence of geogrid on the road embankment.

3.1 Geometry Model

Analyses using plaxis 2D software was conducted to simulate the construction of road embankment on the soft 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 [1].

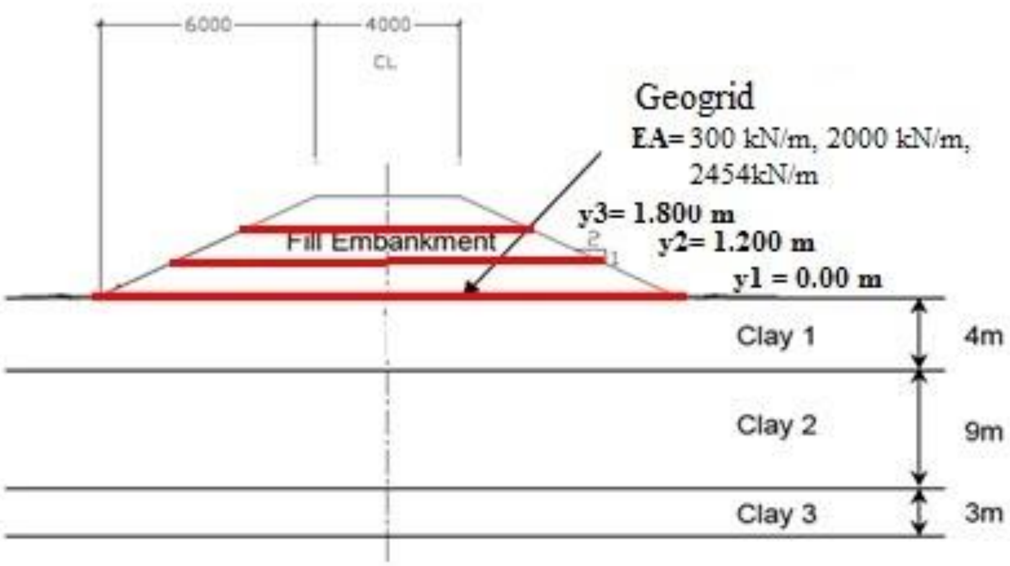

Figure 2: Model geometry

Table 1 shows the data for the soil properties that being inserted in the software while Table 2 shows parameters for reinforced materials which consists the characteristics of 3 different geogrid materials.

Table 1: Soil properties

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

Table 2: Parameters for reinforced materials

Material	Model type	Material type	EA (kN/m)
Polypropylene	Geogrid	Elastic	300 [5]
Woven	Geogrid	Elastic	2000 [6]
HDPE	Geogrid	Elastic	2454 [3]

3.1 Method to Analysis

In this paper, 100 kN of loading being used represents the load from vehicles on the road embankment. 3 different locations of geogrid being applied in the road embankment which have different interval. The first location of geogrid is at the bottom layer of the road embankment. The second location is located at 1.200 m from the bottom and the third location is 1.800 m from the bottom layer.

There are 9 layers of soil in the road embankment in this paper. 30 phases have been created and analyze in the plaxis 2D to identify which location of geogrid gives the least settlement of road embankment. Plus, this paper applied 3 different types of geogrid which have different number of axial stiffness value.

4. Results and Discussion

In the analyses for stresses and strains for the top surface of the embankments, it was observed from Table 5 that the maximum settlement occurs at the different location of geogrid.

Table 3: maximum settlement at different location of geogrid

Type of Geogrid (Material)	EA (kN/m)	Maximum Settlement (m) at Different Location of Geogrid		
		Bottom (y1 = 0.00 m)	Middle (y2 = 1.200 m)	Top (y3 = 1.800 m)
Polypropylene	300	-0.521	-0.574	-0.579
HDPE	2000	-0.549	-0.576	-0.579
Woven	2454	-0.546	-0.576	-0.579

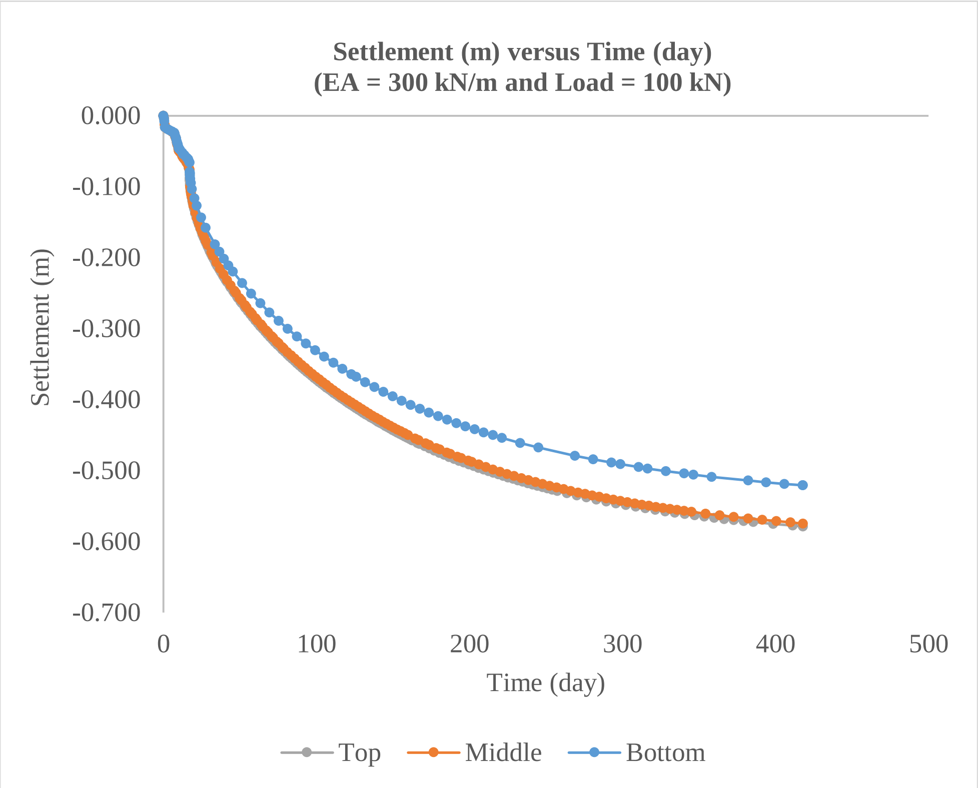

Figure 3: Soil settlement using 300 kN axial stiffness of geogrid

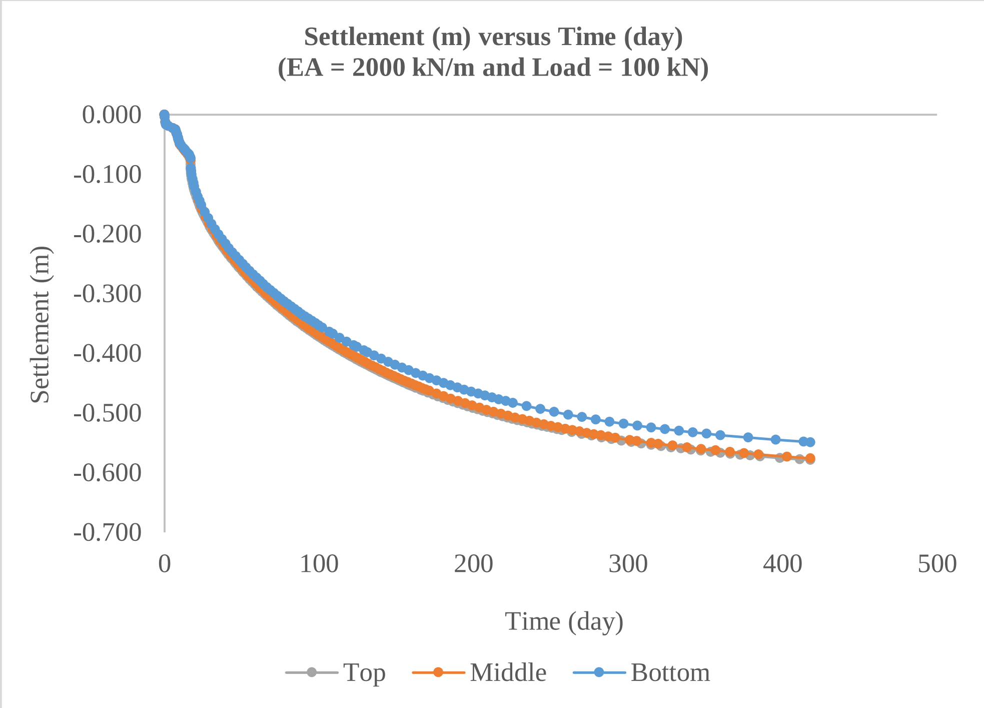

Figure 4: Soil settlement using 2000 kN axial stiffness of geogrid

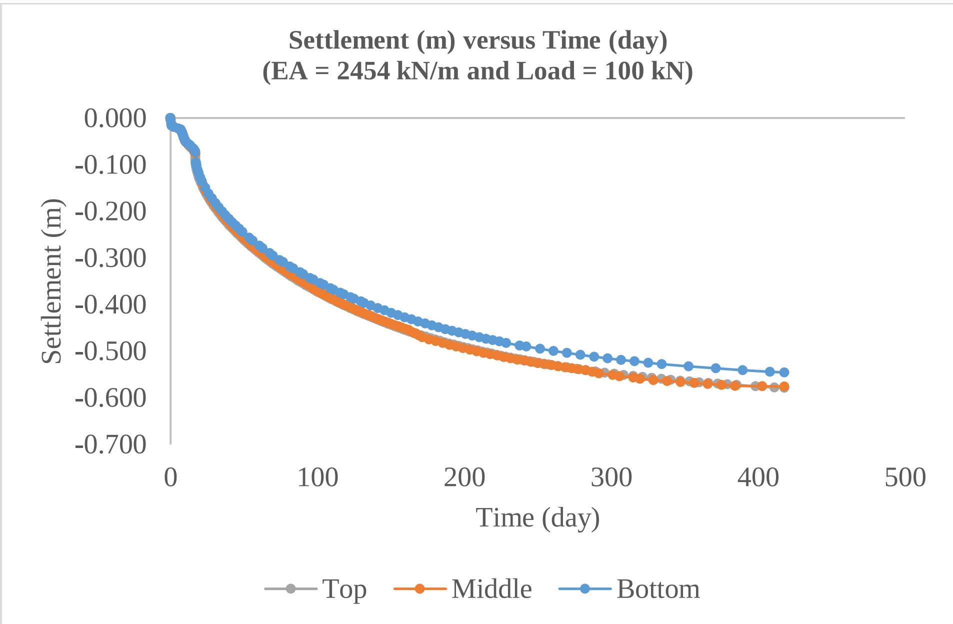

Figure 5: Soil settlement using 2454 kN axial stiffness of geogrid

Figure 3, 4, and 5 shows the result of soil settlement by using different axial stiffness of geogrid which are 300 kN, 2000 kN and 2454 kN and different location of geogrid as per show in figures above. All of the graph shows that the most suitable location of geogrid to be applied in the road embankment is located at the bottom as it shows the least soil settlement. Figure 2 that used 300 axial stiffness of geogrid shows that the maximum settlement for bottom location of geogrid is -0.521 m. Figure 2 that used 2000 kN axial stiffness of geogrid shows that the maximum settlement for bottom location of geogrid is -0.549 m while figure 3 that used 2454 kN axial stiffness shows that the maximum settlement for bottom location of geogrid is -0.546. It shows that the lowest location affects the strength of road embankment as the results shows the least value of settlement.

Figure 2,3 and 4 shows for the middle and top location of geogrid mostly almost the same value of soil settlement. It shows that both locations are not suitable to apply geogrid as it is being laid at the weak location in order to reinforced the structure of soil embankment.

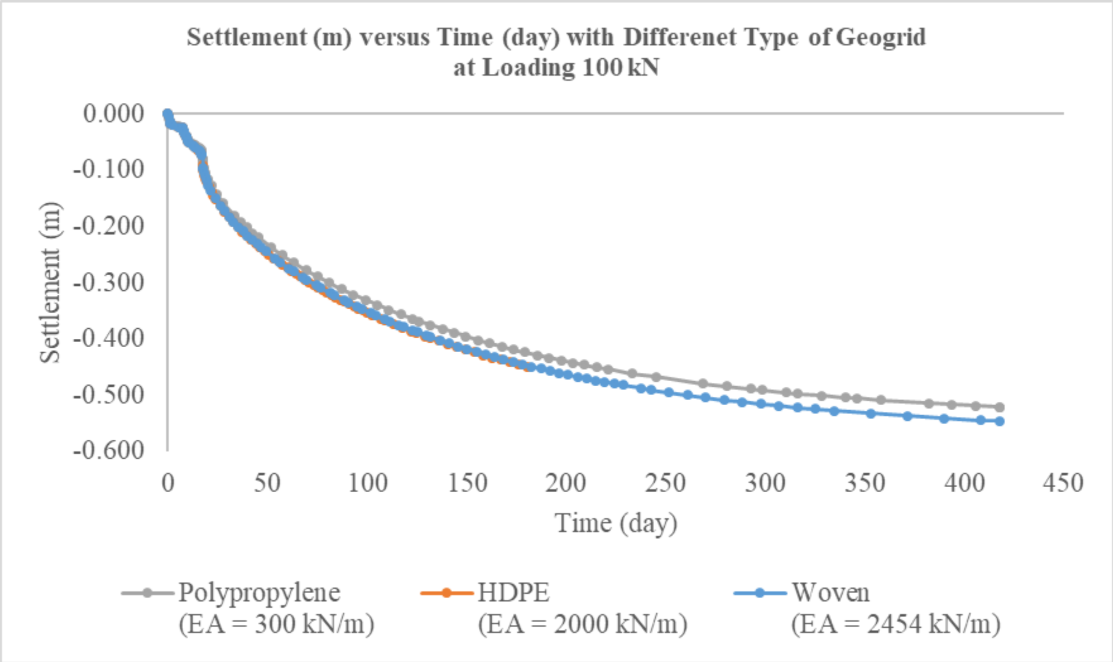

Figure 6: Soil settlement using different axial stiffness

Figure 5 shows the graph of soil settlement on an embankment that used different axial stiffness which are 300 kN/m that is made from polypropylene, 2000 kN/m that is made from HDPE and 2454 kN/m that is made from woven. The graph shows that the geogrid that is made from polypropylene is the best material as it shows the least soil settlement rather than the geogrid that is made from HDPE and woven material. Hence, it states that the geogrid that is made from polypropylene is the strongest material to withstand the load and reinforced the embankment.

5. Conclusion

From the studies it is observed that increase location of geogrid reinforcement increased the settlement of soil embankment. Hence, the lowest location of geogrid shows the best result as it shows the lowest soil settlement. Furthermore, this studies also indicates that propylene which is 300 kN/m axial stiffness shows the best material to be as the geogrid material as it shows the least soil settlement on the embankment. As conclusion, geogrid that made from low axial stiffness value is good to make as soil reinforcement as the results above shows the least value of settlement. Other than that, the lower location of geogrid applied in the road embankment is the best location to applied the soil reinforcement as it shows the least value of settlement rather than any locations.

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