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The Effect of Geocell Reinforced Embankment Construction on the Behaviour of Beneath Soil Layers Using Numerical Analysis

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Abstract. Geocell soil reinforcement method is became one of the common improvement method used in different aspects of geotechnical engineering. The experimental investigation using physical modelling is somehow complicated and needs more financial support especially when using saturated or partially saturated soil. That's why nowadays, researchers are trying to use updated numerical methods to simulate the soil behaviour considering above conditions. In this paper, Geocell reinforcement method in embankment construction has been studied using Mohr-Coulomb model. The embankment is overlaid on two layers of soil with different moisture content conditions. The first layer beneath the embankment is a five-meter layer of dry soil and the second layer considered fully saturated soil. The results indicate that embankment reinforcement by Geocell has no significant effect on the excess pore water pressure while the settlement and stress distribution beneath the embankment is highly affected.

1. Introduction

Constructing embankments over soft soils always is a challenge for geotechnical engineers and needs special techniques to improve the properties of embankment and foundation soils in order to prevent the failure of embankment, because shear strength of subgrade soils is low which cause, excessive consolidation, settlements and sometimes bearing capacity failure. Variety methods have been developed to solve many geotechnical problems like Grouting, piling, geosynthetic reinforcement and etc. [1-6]. geosynthetics are synthetic products used to stabilize the ground and embankments [7]. Geocell is one type of geosynthetic product. As it is well known usage of Geocell layer at the base of embankment has lots of benefits: as an immediate working platform for the construction, more uniform settlements, reduced construction time and eliminated excavation and replacement costs, increased bearing capacity and decreased settlements [8, 9].

Despite several researches that have published and successful practical applications [10], Geocell reinforcement is still not widely used like other conventional soil improvements like Grouting and pilling. In recent decades several laboratory and field research have been conducted to investigate performance of Geocell-supported embankment overlaid on soft soils. Some researchers combined two or more ground improvement methods. Dash and Bora, studied about improved performance of soft clay foundations using stone columns and geocell-sand mattress [11]. The experimental results were obtained in their study confirm that such composite reinforcement is an added advantage over the conventional ones. With provision stone columns, the bearing capacity of soft clay beds can be increase by 3.7-fold and with Geocell reinforcement it is of the order of 7.8-fold. When coupled together the bearing capacity increased by 10.2-fold. Zhang et al., studied about bearing capacity of the soft subgrade soil treated with Geocell reinforcement at the bottom of embankment was proposed based on the study of the reinforcement mechanisms of geocell in embankment engineering [12]. As the embankment settlement increases, the proportion of the increased bearing capacity induced by ‘‘membrane effect’’ of the geocell reinforcement increases, until the reinforcement experiences tensile failure or the embankment foundation is destroyed. When the influence of tension membrane effect of the reinforcement was considered, the results obtained from the proposed method were much closer to the experimental results than those from Koerner’s method when the embankment settlement was large. Krishnaswamy et al. studied experimentally about Geocell reinforcement for construction of embankments over soft clay foundation [13]. They laid embankment with 400 mm height on Geocell that soft clay beneath both of them (figure 1). The geocell reinforcement at the base of the embankment improves the performance of the embankment drastically in terms of load carrying capacity and settlements.

This paper presented a 2D simulation of Geocell reinforced embankment construction that overlaid on two layers of soil with different moisture content conditions and compared the results with same embankment construction without Geocell reinforcement.

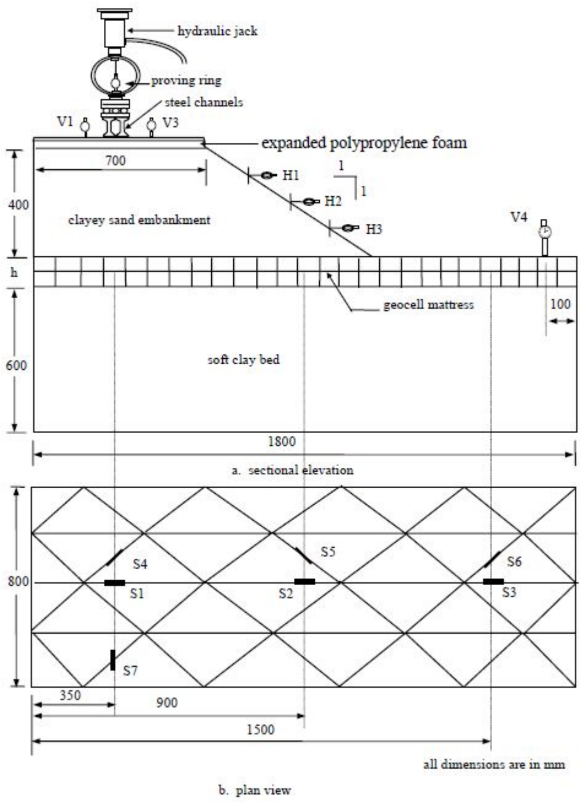


Figure 1. Test setup for Geocell embankment.

2. Numerical modelling and analysis

Nowadays numerical software especially finite element software are one of the most important tools for simulations. In this paper we used ABAQUS finite element software. As stated in the introduction, the research was conducted in order to compare soil behavior beneath geocell reinforced embankment and without geocells.

In this simulation assumed that we have 2 soil layers with 2 moisture content conditions so that the first layer is dry and the second layer is fully saturated and mechanical properties of both layers are same i.e. ground water table is 5 meters below the ground surface. Figure 2 shows embankment structure soil conditions. As shown in figure 2 embankment has 3 layers that separated from each other by geocells and another Geocell is embedded between ground and embankment.

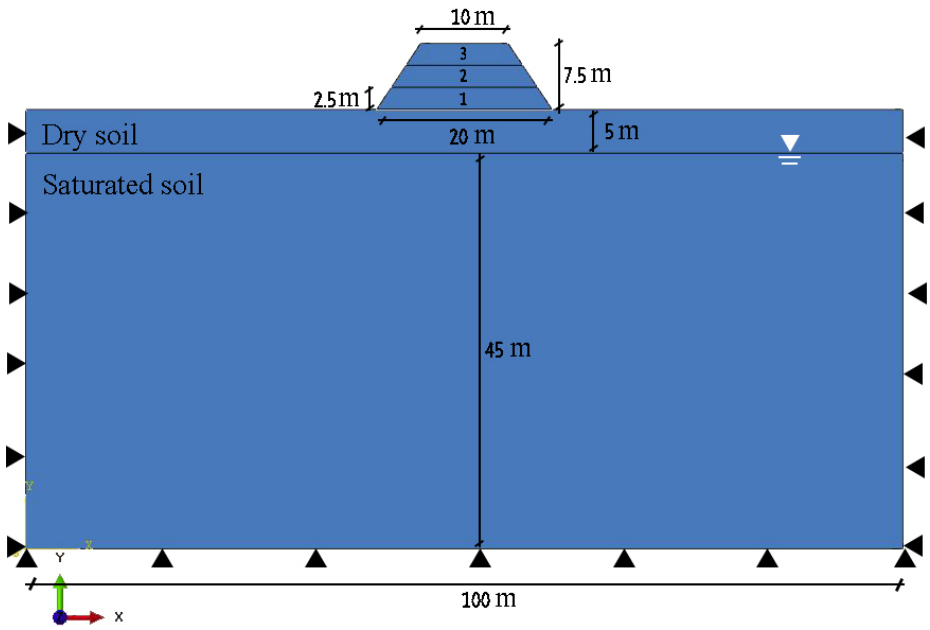


Figure 2. Embankment construction and soil conditions

Mechanical properties of Embankment are same as subgrade foundation. The embankment was constructed in 5 steps that in each step soil layers placed and after soil placement relevant Geocell is laid on each soil layers in separate steps. In the second model all steps are same as first one just steps related to geocells are omitted. In this paper we used Mohr-coulomb constitutive law for soils that mechanical properties of soils are listed in Table1. Geocells have elastic behavior and their displacements are reversible and most of Geocells are made of polymer. Table 2 listed elastic properties of Geocells.

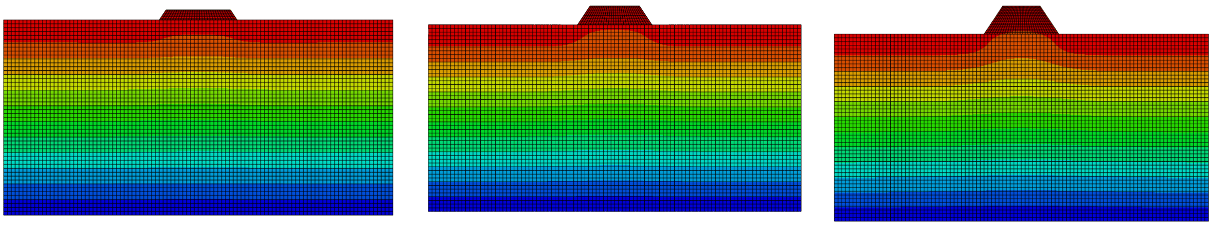
Table 1. Mechanical properties of soil

parameters	$\rho\ (kg/m^3)$	$E\ (MPa)$	υ	k (m/s)	e	φ (°)	ψ (°)	C (KPa)
values	1800	60	0.3	1e-8	0.5	30	0.1	200

Table 2. Mechanical properties of Geocell

parameters	$\rho\ (kg/m^3)$	$E\ (MPa)$	υ
values	900	75	0.3

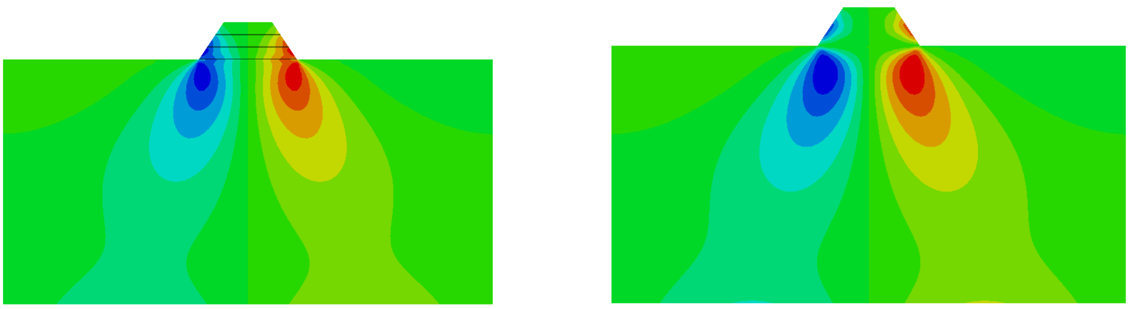
Each layers of soils and Geocells that placed above ground applied their own weight in gradual steps. Figure 3 shows stress effect of construction steps.



a b c

Figure 3. Embankment construction effect on stress a) first stages of construction b) second stages of construction c) third stages of construction

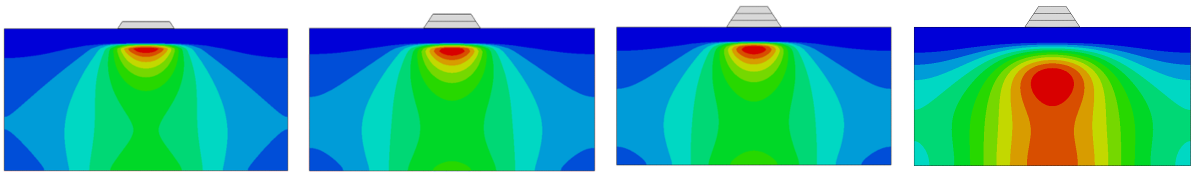
Strain localization for the first and second model are demonstrated in Figure 4 and confirms effects of geocells in embankment and foundation behaviors.



a b

Figure 4. Shear strain localization a) with Geocell b) without Geocell

Figure 4 shows that, in reinforced embankment, shear strain localization has continuous cantor and under the embankment it is smaller than embankment without Geocells, in other words we have bigger shear strain localization under embankment when it doesn't have embedded Geocells. Results indicate that Embedded Geocells have minor effects on pore water pressure. Figure 5 shows pore water pressure changes during construction, note that after placement of last embankment layer, consolidation is applied to the model and in this step pore water pressure dissipated gradually by the time.



a b c d

Figure 5. Pore water pressure changes during construction and consolidation stress a) first stages of construction b) second stages of construction c) last stages of construction d) consolidation

Figure 6 indicates the influence of embedded Geocells in embankment on subgrade foundation settlement, it shows when we use Geocells in embankment, the peak settlement that occurred in the middle of bottom is smaller than second simulation.

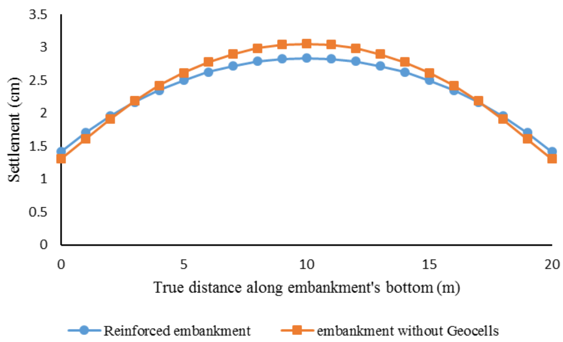


Figure 6. Settlements comparison

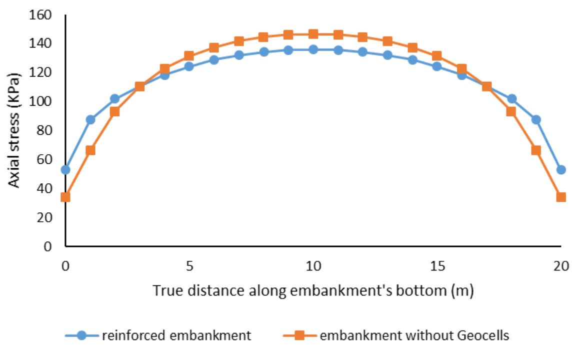


Figure 7. Axial stresses comparison

Figure 7 demonstrated effects of embedded Geocells on stress status below the embankment. The results indicates that embedded Geocells have more effect on stress status and in reinforced embankment stress under the embankments is lower than other one.

3. Conclusions

As discussed above, several methods were proposed to reinforce embankments and other geotechnical structures. One of these methods that has many advantages in compare with other methods is usage of Geocells as reinforcement in geotechnical structures like embankments. In this paper simulated 3 layers embankments that laid over ground that the ground has 2 different moisture content conditions. The results indicate that application of Geocells is more to settlement and stress control and it has minor effects on pore pressure. Application of Geocells as embedded reinforcement in embankment caused smaller settlement and stress under embankment in compare with embankment without embedded Geocells. The results directly relate to Embankment scale i.e. large embankments, Geocells have significant effects on results and it is obvious that differences in results of reinforced embankment and simple embankment are remarkable. Another aspect that has significant effects on results is number of Geocells that embedded in the embankments, it means that if we use more Geocell layers as reinforcement, differences between results of reinforced embankment and simple embankment are more remarkable.

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References

[1] Y. Beju, J. J. I. J. o. G. Mandal, and G. Engineering, "Combined use of jute geotextile-EPS geofoam to protect flexible buried pipes: experimental and numerical studies," vol. 3, no. 4, p. 32, 2017.
[2] A. Hegde, T. J. G. Sitharam, and Geomembranes, "Experimental and numerical studies on protection of buried pipelines and underground utilities using geocells," vol. 43, no. 5, pp. 372-381, 2015.
[3] M. Mengelt, T. Edil, C. J. G. E. R.-. Benson, Department of Civil, and U. o. W.-M. Environmental Engineering, Madison, Wisconsin, "Reinforcement of flexible pavements using geocells," p. 180, 2000.
[4] S. Moghaddas Tafreshi, N. Joz Darabi, A. Dawson, and M. J. I. J. o. G. Azizian, "Experimental Evaluation of Geocell and EPS Geofoam as Means of Protecting Pipes at the Bottom of Repeatedly Loaded Trenches," vol. 20, no. 4, p. 04020023, 2020.
[5] S. Moghaddas Tafreshi, O. Khalaj, and A. J. G. I. Dawson, "Pilot-scale load tests of a combined multilayered geocell and rubber-reinforced foundation," vol. 20, no. 3, pp. 143-161, 2013.
[6] S. Moghaddas Tafreshi, O. Khalaj, and M. J. G. I. Halvaee, "Experimental study of a shallow strip footing on geogrid-reinforced sand bed above a void," vol. 18, no. 4, pp. 178-195, 2011.
[7] O. Khalaj, S. Moghaddas Tafreshi, B. Mask, A. R. J. G. Dawson, and Engineering, "Improvement of pavement foundation response with multi-layers of geocell reinforcement: Cyclic plate load test," vol. 9, no. 3, pp. 373-395, 2015.
[8] O. Khalaj, S. N. M. Tafreshi, B. Masek, and A. R. Dawson, "Improvement of pavement foundation response with multi-layers of geocell reinforcement: Cyclic plate load test," (in English), *Geomechanics and Engineering,* vol. 9, no. 3, pp. 373-395, Sep 2015.
[9] L. Li, F. Cui, Z. Hu, and H. Xiao, "Experimental Study on the Properties of Geocell-Reinforced Embankments," in *Proceedings of China-Europe Conference on Geotechnical Engineering*, 2018, pp. 1160-1163: Springer.
[10] S. M. Tafreshi, O. J. G. Khalaj, and Geomembranes, "Laboratory tests of small-diameter HDPE pipes buried in reinforced sand under repeated-load," vol. 26, no. 2, pp. 145-163, 2008.
[11] S. K. Dash, M. C. J. G. Bora, and Geomembranes, "Improved performance of soft clay foundations using stone columns and geocell-sand mattress," vol. 41, pp. 26-35, 2013.
[12] L. Zhang, M. Zhao, C. Shi, H. J. G. Zhao, and Geomembranes, "Bearing capacity of geocell reinforcement in embankment engineering," vol. 28, no. 5, pp. 475-482, 2010.
[13] N. Krishnaswamy, K. Rajagopal, and G. Madhavi Latha, "Geocell reinforcement for construction of embankments over soft clay foundation," in *Proceedings of 2nd International Conference on Ground Improvement Techniques, Singapore, October*, 1998, pp. 251-258.