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Performance Evaluation of Geocell Reinforced Unpaved Roads

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Abstract. This paper describes the utility of geocell, a three-dimensional product of geosynthetic family to reinforce the weak subgrade for the unpaved roads. The unpaved roads are majorly used as construction roads, access roads, maintenance gallery of any infra projects. Overnight rainfall or repetitive loading can cause severe damages on this type of construction roads especially which are resting on very weak subgrade. As geocell can effectively provide lateral confinement to infill material to increase the modulus and bearing capacity of the subgrade, compared to other alternatives like chemical stabilization or replacing the weak soil with stronger one the geocell based unpaved roads can be economic and cheap alternative. A major bridge project in between Assam and Meghalaya on the river Brahmaputra has been identified as the project of implementation. The trial section of 150 m has been identified to implement the geocell in single and two layers to reinforce the subgrade soil. The available riverbed sand has been used as the infill material of the geocell pockets. Field plate load tests have been performed to check the pressure-settlement behavior of the reinforced and unreinforced sections. Use of two layers of geocell has significantly increase the strength and stiffness of the unpaved roads. The test showed that the geocell reinforcement reduced the permanent deformation and increase the percentage of elastic deformation of the granular subgrade. The constructed unpaved roads already sustained one monsoon without any significant damage.

Keywords: Shallow Ground Improvement, Geocell, Weak Subgrade, Unpaved Roads.

1 Introduction

Application of geosynthetics inclusions in the form of two-dimensional form (geotextiles and geogrid) and three-dimensional form (geocell) have been widely acceptable in all the geotechnical applications e.g., pavement layers [1, 2], slope protection layers [3–5], foundation bed layer on the soft soil [6] , retaining structures [3, 7]. The geocell has been widely used for reinforcing granular bases under different loading conditions such as static and repeated loadings. The construction approach roads are integral component of any infrastructure projects like highways, expressways, dedicated freight corridors. In country like India most of the unpaved constructed over weak subgrade, and soft soil conditions. The geocell can be used as shallow ground improvement measures in this unpaved road construction.

The damages in construction roads or approach roads are predominant due to overnight rainfall and typically monsoon season reduces the operational efficiency of whole process. The damages of the unpaved approach roads have been shown in Fig. 1, where few days rainfalls cause significant delay in the project. Out of different solutions inclusion of geosynthetic reinforcements (geogrids, geotextiles) [8], lime-fly ash stabilization [9, 10], utilization of waste tyre, sandbags [11] are most available options as shallow ground improvements for unpaved roads.

(a)

(b)

Fig. 1. Operational delay on weak subgrade in monsoon.

In the present study, the application of geocell as the shallow ground improvement measures has been given major emphasis for the construction of unpaved roads. The performance of the geocell reinforced layer has been studied under repeated wheel load, and the influence of multilayer geocell has been investigated. The field plate load tests have been performed for both reinforced and unreinforced stretch of the road.

2 Site Description

The reported construction approach road is part of the 18.2 km long bridge projects between Assam and Meghalaya district of India. The proposed bridge is supposed to be the connectivity between the two districts. The site location has been shown in Fig. 2.

Fig. 2. Location of the proposed bridge between Dhubri and Phulbari, India.

The proposed trial section for geocell reinforced construction road has been located in Dhubri side where cost of the aggregates is too high and there is no availability of required riverbed material (RBM).

3 Sub-soil Profile Characteristics

The present trial stretches mostly consists of loamy to sandy-loam soil. Total five bore holes have been drilled in the vicinity of the proposed trial stretch. In the proposed location up to 0.5 m depth loose grey silty sand has been observed, followed by up to 8 m depth firm grey silty poorly graded fine sand has been observed with high mica content with SPT N value more than 20. The idealized soil profile in this location has been shown in Table 1.

Table 1. Idealized soil profile in proposed construction road.

Depth (m)	Soil Profile	SPT N value	IS Symbol	Clay (%)	Silt (%)	Sand (%)	LL (%)	PI	NMC (%)
0.5 m		6	SM	28	60	12	39	14	26
7.5		15	CL	14	70	16	33	19	25
3.0		21	SM	0	0	95	-	NP	20

The stop soil condition of the proposed location has been shown in Fig. 3. The top soil shows the existence of the very fine sand on the entire area.

Fig. 3. Typical site condition in the proposed location.

4 Characteristics of the Geocell

Geocells are commonly made up of high-density polyethylene (HDPE), with three dimensional arrangements as shown in Fig. 4. In the present study, used geocell is made of a type of a non-woven polymeric geotextile. The material properties of the HDPE geocell has been discussed in Table 2. The geocell layer has been placed in single layer and double layer with the thickness of 75 mm for each layer.

Fig. 4. The 3D arrangement of HDPE geocell.

Table 2. Material properties of the HDPE geocell.

Properties	Values
Nominal wall thickness	1.5 mm
Polymer Density	0.965 gm/cm^3
Cell depth	100-150 mm
Pocket width	100 mm
Pocket length	170 mm
Tensile strength-perforated	20 kN/m
Junction peeling strength	20 kN/m

5 Field Plate Load Test on Proposed Section

In the present study, the construction roads have been proposed for the operation purpose in this project. The cross section of the proposed stretch has been shown in Fig. 5. The HDPE geocell has been placed in between the 100 mm thick base course (Wet Mix Macadam) and 250 mm thick granular sub-base layer. The fine sand has been used as the infill material for geocell pocket. The in-situ plate load tests have been conducted to compare the reinforced and unreinforced section.

The following apparatus have been required to conduct the field plate load test: i) circular steel plate of 300 mm diameter and 30 mm thickness. ii) hydraulic jack of capacity 300 kN, iii) supporting steel beam of length 5 m, iv) dial gauges having capacity of 0.01 mm, v) plumb bob, vi) spirit level, vii) short steel supporting members, vii) loaded truck. For this purpose, the proposed trail stretch of 100 m length has been identified. The static load using hydraulic jack has been applied on the trail section monotonically at a rate of 1.8 kPa per second. To measure the settlement, bearing capacity value for both the reinforced and unreinforced section have been measured considering single and multi-layer geocell. Strain gauges have been used to measure the strains developed at different locations of the geocell and at the bottom of WMM layer. The strain gauges have grid resistance of 110±0.5% in ohms, and grid length of 6.20 mm and width of 3.2 mm, respectively. The strain gauges have been rated for a maximum temperature of 80°C. Strain gauges have been affixed on different locations of geocell. The displacement transducers have been used to measure the vertical displacements at the interface between WMM layer and geocell reinforced base layers. The steel loading plate of 300 mm in diameter and 30 mm in thickness have been used to apply the static load on the trial sections.

The static load has a peak value of 40kN. The peak value of the load has been selected to simulate the single axle load of 40 kN in magnitude, which corresponds to a tyre pressure of 550 kPa. The schematic diagram of the loading system has been shown in Fig. 6. The collected undisturbed soil sample from the subgrade has shown CBR value of 8% and that of base course has shown 16%.

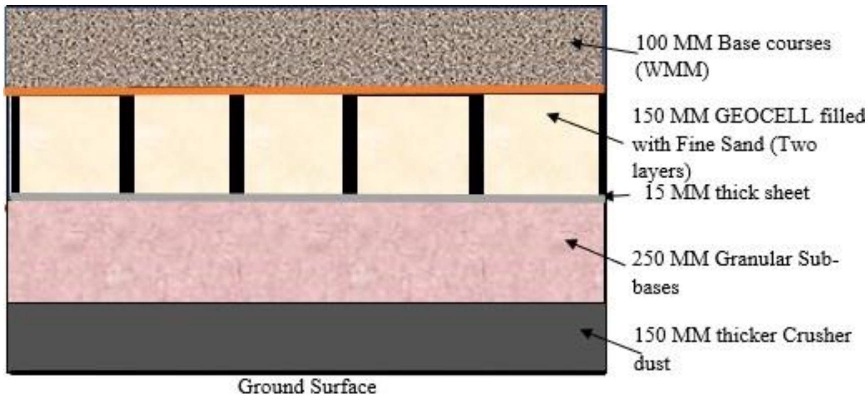

Fig. 5. Proposed construction road section using geocell.

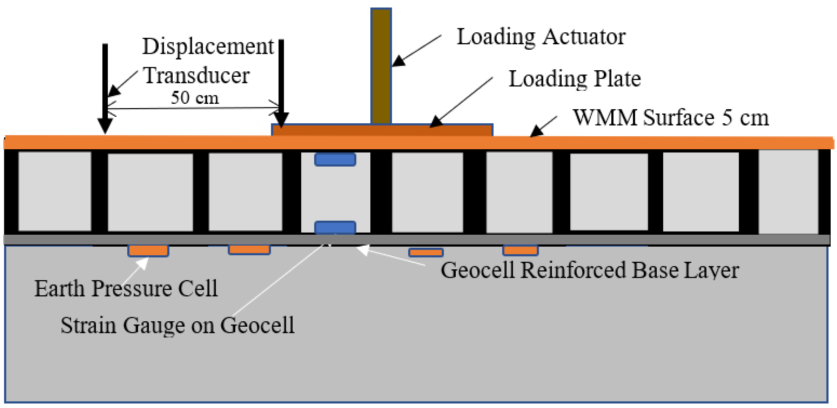

Fig. 6. Schematic diagram of field plate load test set-up.

6 Results and Discussions

Fig. 7 shows the distribution of load and settlement on the proposed section. The section with more geocell layers has indeed higher load carrying capacity. The increase in load carrying capacity with the geocell reinforcement layer could be similar to the finding of Latha et al. [12]. The filled geocell with sand acts as an integrated material which is equivalent to cohesive material. The extra apparent cohesion is contributed to the overall shear strength of the layer. The geocell filled sand layers have been behaved as composite layer to provide additional shear strength. Owing to the three-dimensional nature with perforation geocell provides the stress dispersion at the base of the loading platform. It behaves like semi-rigid slab disperse the loads coming from the surcharge and gravity. The reduction in the settlement in the range of 25-30% have been observed with single layer of geocell as compared to unreinforced section, whereas 30-40% have been observed with two layers of geocell. The two layers of geocell has improved the settlement reduction by 15-30% as compared to single layer of geocell.

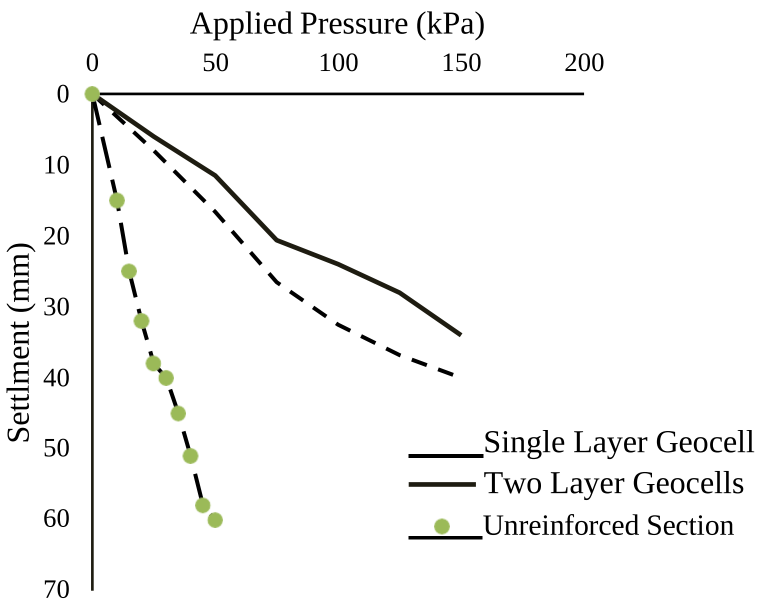

Fig. 7. Pressure settlement distribution from in-situ load tests.

Fig. 8 shows ground surface settlement profile captured by displacement transducer. Both the single and two layers geocell cases, the ground surface tends to deform in relatively larger area. As geocell filled sand layers acting as the composite system, the settlement observed in the far away from the loaded region. The performance of both the layers geocell have been checked with different passes of dumper to check the undulated level. The heave has been observed in case of unreinforced section. The deformed geocell filled sand layer induced large passive earth pressure in the soil within cell pockets, which reduces the heave.

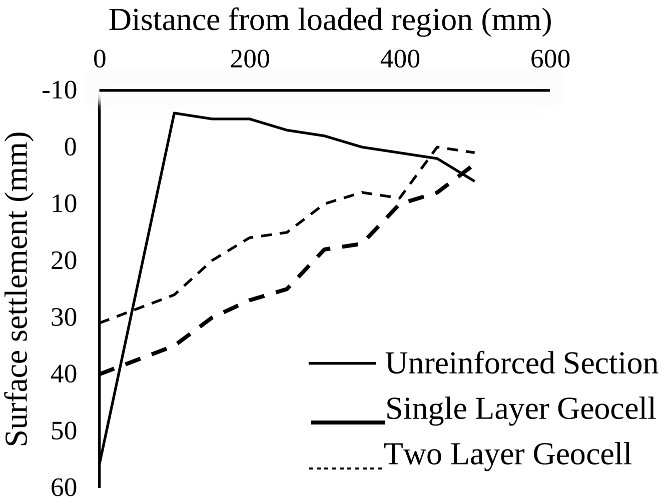

Fig. 8. Ground surface profile (negative value means ground heave).

The performance of the top layer has been checked with 20-ton million standard axle (msa) loaded dumper with two different passes one with four another with six. The top surface profile has been shown in Fig. 9. The two-layer geocell has shown very minimal depression marks on the top due to six passes of dumpers.

(a)

(b)

Fig. 9. The top surface after (a) four-wheel passes, (b) six-wheel passes.

7 Conclusions

The present study summarized the field experimental work on shallow ground improvement in unpaved construction roads using geocell. The unpaved construction roads are integral part of the highway project, under intense rainfall geocell stabilized roads can perform effectively. To check the performance of geocell stabilized roads in-situ field plate load tests have been conducted. The increased in load carrying capacity due to use of single and two layers geocell has been resulted from the apparent cohesion provided by the geocell and sand as an integrated composite material. The deformed geocell layer induced large passive earth pressure in the soil within the cells to distribute the load over larger area of ground.

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