Green Cell Reinforcement in Soil

Chapter · December 2019

DOI: 10.1007/978-3-030-26365-2_79

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***Abstract*—Development of the infrastructure is the most important need in the present time. To fulfill the infrastructural need of population, small multi-story buildings, express highways, high speed rail tracks, new bridges, airports etc. are required to be constructed. Ultimately loads from such structure come to the ground. Due to space constrains many times construction takes place on poor soil. Construction over poor soil with high loads is a challenge for civil engineers. Replacement of weak soil by some strong soil or improvement of engineering properties of weak soil by different ground improvement techniques are used in such situation.**

Geosynthetics are being widely used for the last two decades as soil reinforcement to improve the quality of soil owing to their ease of operation and overall cost. Screw pine-cell is the most advanced form of Geocell. It is a three dimensional, natural, honeycomb like structure of cells interconnected at joints. The soil particles can be trapped inside these cells providing an overall confinement to the soil layer and improves its properties regarding support to civil engineering structures[2].

In this project we mainly focus on the increasing of load carrying capacity and reduce the settlement of weak soil in Kerala with Screw pine-cells.

Key words

Green cell, Reinforcing weak soil, Load carrying capacity

I. INTRODUCTION

Nowadays most of the countries are giving so much importance to the infrastructural growth. But the soil around us are not of good quality, thus designing and construction of various works on these weak and compressible soil lead to many problems such as losing of shear strength and excessive settlement etc. Hence the stabilization of the soil has been an area of major concern in the field of construction. Soil stabilization means to improve the engineering properties of the soil and make it more stable. So, here we use the concept of cellular confinement system. This method creates a new composite form that possesses mechanical and geotechnical properties. Geocells are three dimensional honeycombed synthetic cellular structures. These 3 dimensional zone of confinement infilled with sand reduces the lateral movement of soil particles while vertical loading act on it, which results in high lateral stress and resistance on the cell-soil interfaces.

We introduce the Green cells which are prepared by naturally and locally available screw pines, since synthetic material are not economical and eco-friendly. The screw pines are cut into thin layer of strips and are woven together using galvanized wires to form a grid as shape resembling geocell. These cells possess more lateral and vertical confinement. This proves to be a very good improvement in the footing performance especially when provided as a mattress. Since these are obtained naturally, it is eco-friendly, it possess no negative impact to the environment.

II. METHODOLOGY

The prime objective of our project is to reduce settlement of foundation soil by reinforcing it with green cell. Thus the reinforcing property of green cell is checked by applying load on model test sample and noting settlement which is then compared with unreinforced soil.

A. Materials required

For experiment the materials required are weak soil, sand for infilling green cell, screw pine for making green cell. Various tests are to be done on soil and sand to understand the properties and to check whether soil is weak or not.

B. Weak soil

The foundation soil was collected from field. In order to prove the selected soil is weak various tests were conducted like Atterberg's limit, Specific gravity test for soil, Unconfined compression test, Particle size distribution, Standard proctor test and Direct shear test.

C. Green cell

Green cell is made with screw pine in the form of three dimensional geocell. The screw pine are easily available in Kerala and for our project screw pine strips with 10mm width were collected and waved to form grids which were then tied at required interval with galvanized steel wire of 1mm to form cells. The size of the green cell has decided based on similitude with commercially available geocell. The sizes of green cell has been made as 125mm x 105mm for inside diagonals and height as 75mm which is half of the geocell with cell aperture size 250mm x 210mm x 150mm.

In our project we compared the property of green cell reinforced soil and unreinforced soil under three cases with different cell sizes of 125mm x 85mm, 125mm x 105mm and 145mm x 105mm with same height of 75mm.

Fig. 1 Screw pine strips, grid and green cell

III. TESTS ON SOIL

1) Results obtained

TABLE I
TEST RESULTS ON WEAK SOIL

Sl.No	Description	Values
Atterberg's limit		
1	Liquid limit	75%
2	Plastic limit	66.67%
3	Flow index	55.14%
4	Toughness index	0.3010
5	Plasticity index	16.67
6	Shrinkage index	44.1483
7	Shrinkage limit	22.5217
8	Shrinkage ratio	1.6381
9	Volumetric shrinkage	69.943
Specific gravity		
1	Specific gravity of soil	2.584
Unconfined compression test		
1	Unconfined compressive strength q_u	4.668 kN/m2
2	Un drained shear strength	2.334 kN/m2
Particle size distribution		
1	Uniformity coefficient C_u	2.714
2	Coefficient of curvature C_c	1.806
Standard proctor test		
1	Maximum dry density	0.927
2	Optimum moisture content	11.11%
3	Zero air void line (100% saturation)	1.898
Direct shear test		
1	Angle of internal friction	9.349°

The liquid limit of soil is obtained as 75% which is greater than 50% hence the soil is highly compressible. The type of soil having a plastic limit greater than 30% is highly plastic in nature and here we have a plastic limit of 66.6% which indicate that soil is highly plastic. The specific gravity value we obtained is 2.584 which fall under organic soil. For Unconfined compression test we have obtained a value of 4.668KN/m² as unconfined compressive strength. The unconfined compressive strength between 0 - 25 indicates that the soil is having very soft consistency. The graph obtained for particle size distribution shows that the soil is poorly distributed. In case of direct shear test it is seen that the sand used as infill is loose as it has an angle of friction of 9.349º. Standard proctor test was conducted and the optimum moisture content was obtained as 11.11% with maximum dry density of 0.927. This test is important for the preparation of foundation bed.

IV. LABORATORY LOAD CARRYING TEST

Differential settlement between different parts of structure can endanger the entire structure. Providing reinforcement in soil can avoid such situation in construction fields. The effect of settlement depends upon many factors such as magnitude, type of structure etc. Load bearing text conducted for green cell reinforcement helps to find out how much settlement can be reduced in soil by using this particular method. Load bearing test is conducted for both plain soil and soil placed with green cell of three different sizes .The size of the cells were selected by comparing with the size of commercial geocell. For conducting load bearing text we have constructed a steel tank of size 450mm x 450mm x 30mmm.This steel tank represents the land area where there is a chance for settlement.

First we determined the deformation values for plain soil which is very weak. Plain soil is set as the standard for conducting other tests because based on settlement in plain soil we will compare the settlement values for soil were green cell is provided as reinforcement. Foundation bed is prepared using natural clayey soil which is very weak. Filling of soil is done in three layers by providing optimum moisture content at which it obtains maximum dry density and 25 blows for each soil layer. Constant fall of height for each blow should be maintained throughout the filling inside steel tank .The sides of steel tank should be covered with polyethylene sheet in order to avoid side friction. For plain soil test we fill the weak soil upto a height of 300mm. As a representation of footing we are placing plywood of size 75mm x 75mm x 15mm. Load is applied to the soil using universal testing machine. Steel tank is placed inside universal testing machine and load is applied over center of plywood without having any eccentricity. Load values are noted from dial clock and corresponding settlement values are noted from deformation scale. Load application is done till the reinforcement fails .Second part of test is to conduct the experiment after placing green cell reinforcement in soil. Here we fill soil upto height of 200 mm and optimum moisture content is added to soil at which it obtains maximum dry density. Green cell which is having a cell size of 125mmx85mmx75mm is placed over weak soil. The placing of green cell should be always in fully stretched manner inside the steel tank. Cell pockets of green cell are infilled with sand which gives green cell more stability. Above the green cell layer we will place the weak soil with same water content and plywood of same size as a representation of footing. Loading and corresponding settlement values are noted. Results show that settlement values are lesser for reinforced soil when compared with that of plain soil. This cell is the which is having maximum number of cell pockets with minimum cell area.

After successfully completing first green cell reinforced test, second green cell of size 125mm x 105mm x 75mm is reinforced in soil inside steel tank with similar arrangement which is given for first green cell and load settlement values are noted from deformation scale. Last test is conducted for green cell of size 145mmx105mmx75mm.This the largest cell size among other three cell sizes hence more amount of sand is required as infill .Similar to other two cells, load application arrangement remains same for this cell size too. Settlement values are noted according to the applied loads. Load application for all three cell sizes remains the same.The reason behind load bearing tests conducted for three cell size is in order to make a comparison among various cell sizes and finally to find which cell size is having least settlement. From the values collected it is understood that performance of green cell reinforcement stabilizes the soil.

V. RESULTS AND DISCUSSIONS

A. Load settlement curve

In this chapter, the results obtained from Load carrying tests on green-cell reinforced soil along with the unreinforced one are presented. In order to evaluate the performance improvement due to reinforcements, reference tests were carried out with unreinforced soils as well. The obtained results are plotted as load settlement curve.

TABLE I
LOAD CARRYING TEST OBSERVATIONS

Load (KN)	Settlement (mm)			
	Plain soil	Cell aperture size 125mm*105mm	Cell aperture size 125mm*85mm	Cell aperture size 145mm*105mm
0	0	0	0	0
5	10	8	6	7
10	15	12	9	11
15	18	14	11	13
20	20	16	12	15
25	24	18	14	17
30	26	20	15	18
35	30	22	17	20
40	35	24	18	22

Combined load settlement curve was used to represent the load-settlement response of the three different cell size cases along with unreinforced soil case. The post-test exhumation of the green cell shows the deformation on the ribs. Out of the three different cell sizes used in the tests, the performance of the cell size 125mm × 85mm was found to be better compared to the other two. The maximum load taken by unreinforced soil was observed as 40 KN and the settlement of footing at that load was 35 mm. For the green cell reinforced soil, the settlement has reduced much more at the same level of load application. Thus it was found from the studies that increase in load carrying capacity and reduction in the settlement of the soil both takes place because of green cell reinforcement. The settlement was least for the cell with least single cell area of 125 mm x 85 mm.

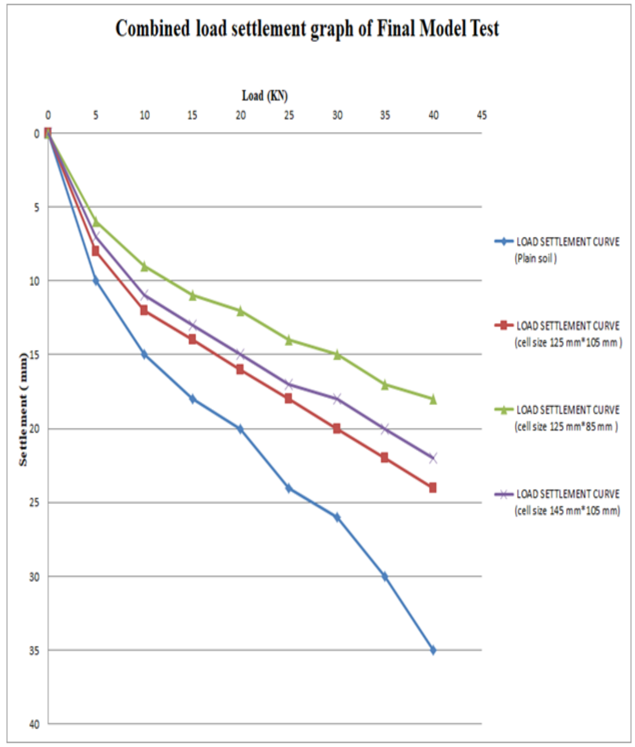

Fig. 2 Combined load settlement graph

B. Load carrying capacity improvement factor (IF)

The extent of improvement in the load carrying capacity due to the different cell sizes was quantified more precisely using load carrying capacity improvement factor. The increase in the load carrying capacity due to the provision of the reinforcement can be found through a non-dimensional parameter called load carrying capacity improvement factor (IF), which is defined as,

$$IF = q_r / q_o$$

Where q_r is the load carried by the reinforced bed at a particular settlement and q_o is the load carried by the unreinforced bed at the same settlement[1]. The improvement factor graph was drawn with reference to the load carrying capacity of the unreinforced soil. The Improvement factor calculation is shown in the following table and its graph is plotted below it.

TABLE I
PRELIMINARY PATCH SPECIFICATIONS

Settlement (mm)	Load taken				Improvement factor for load carrying capacity $IF = q_r / q_o$		
	By Plain soil (q_o)	By Reinforced soil with (q_r)					
		Cell size 125mm x 105mm	Cell size 125mm x 85 mm	Cell size 145mm x 105 mm	Cell size 125mm x 105 mm	Cell size 125mm x 85 mm	Cell size 145mm x 105 mm
6	3	3.75	5	4.28	1.25	1.66	1.42
8	4	5	8.33	6.25	1.25	2.08	1.56
10	5	7.5	12.5	8.75	1.5	2.5	1.75
12	7	10	20	12.5	1.42	2.85	1.78
14	9	15	25	17.5	1.67	2.77	1.94
16	11.67	20	32.5	22.5	1.71	2.78	1.92
18	16	25	40	30	1.56	2.5	1.87

Figure 3 represents the variation of the load carrying improvement factors with the footing settlement for green cell with different cell sizes. It was found that the IF values increase with the increase in the settlement. For the green cell with cell size 125 mm × 850 mm, the maximum IF = 2.85 was observed at settlement = 12mm. The IF curve had a parabolic shape with IF value increasing initially and later decreasing slowly. IF values vary from minimum to maximum in a range between 1.25 to 1.71 for the cell size 125 mm × 105 mm, between 1.66 to 2.85 for the cell size 125 mm × 850 mm and between 1.42 to 1.94 for cell size 145 mm × 105 mm. Green cell with cell size 125 mm × 850 mm were proved to be the better reinforcement as the improvement factors observed were higher as compared to other two green cells.

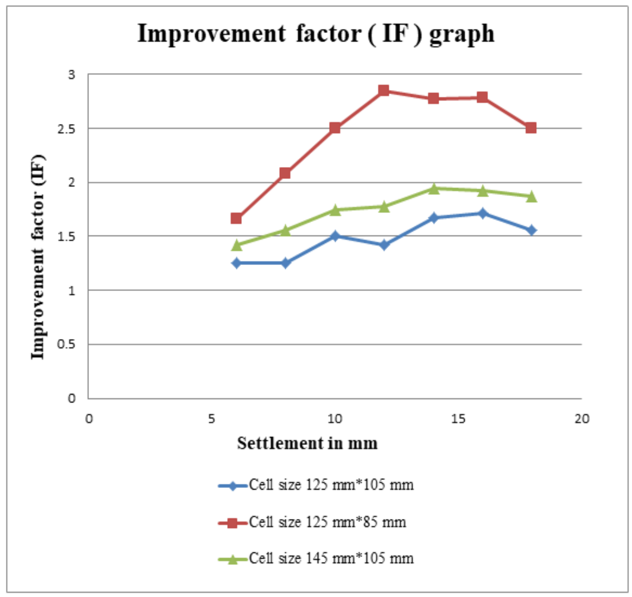

Fig. 3 Improvement factor (IF) graph

VI. DISCUSSION AND CONCLUSIONS

From the results of laboratory investigation performed on a clay bed reinforced with natural screw pines, we can conclude that this method is the best one in terms of cost effectiveness, bearing capacity improvement and reduction of differential settlement. Also the green cell confinement provides all round confinement to the materials and hence prevents the lateral spreading of soil on the application of load. Sizes of cell pockets are found to be the significant parameters for compressive strength because when tested, it is observed that cells with minimum cell area and maximum number of perfect cell pockets possesses least settlement. While considering the improvement factor it is maximum for the above type of cell again.

Hence from our project we concluded that the green cell of size 125mm x 85mm x 75mm was the best among the three green cells we have considered. So these results will be very helpful in providing guidelines for design and construction of various foundation reinforcement.The study has its own limitations as it is a model test and only three different sized cells are considered, thus overall behaviour of the green cell reinforced soil is of interest for future research.

VII. ACKNOWLEDGEMENTS

The authors would like to thank Vasudha V, Assistant Professor Sahrdaya College of Engineering and Technology, for guidance and support.

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