Improvement of Bearing Capacity of Soft Soil Using Coir Geocells

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ABSTRACT: This paper deals with the behaviour of geocells made of coir, under monotonic loading condition. The tests were carried out on square footing supported by dense sand layer underlain by soft clay bed with and without geocell reinforcement in the sand layer. The studies have shown that, with the provision of geocell reinforced sand cushion, there is a substantial reduction in settlement of the underlying soft soil due to modified stress distribution. The beneficial effect in terms of increased bearing capacity and reduced settlement is related to the width, height and pocket size of geocell mattress. Square geocells of overall width of 3 times, cell size of half times, and height of cell equal to width of the square footing gives better performance.

1 INTRODUCTION

The improvement of bearing capacity of soft soil may be undertaken by a variety of ground improvement techniques including stabilization of soil or the introduction of reinforcement. The more recent advancement of reinforced soil is to provide three dimensional confinements to soil by using geocells. Geocell foundation mattress consists of a series of interlocking cells, constructed from polymer geogrids, which contains and confines the soil within its pockets. It intercepts the potential failure planes because of its rigidity and forces them deeper into the foundation soil, thereby increasing the bearing capacity of soil. Geocell reinforcement arrests the lateral spreading of fill soil and creates a stiffened mat to support the foundation thereby giving rise to higher load carrying capacity.

Several investigations have been reported on the use of synthetic geocells to improve the bearing capacity of weak soils. Dash et al., (2001) has been found that geocell enhances the footing performance on sand and it was also found that the optimum width of geocell mattress is around 4 times the width of footing. The studies have been conducted on geocell reinforced sand over soft clay bed and it has been found that geocell reinforcement increased the load carrying capacity of soft soil (Dash et al., (2003) and Sireesh et al., (2009)). The studies on the use of braided coir rope have been conducted by Vinod et al., (2009) and the results show that there is considerable increase in the strength of soil.

In this paper, investigation is carried out on the reinforcing efficiency of geocells made from woven coir within a homogeneous clay bed supporting a square footing.

2 EXPERIMENTAL PROGRAMME

2.1 *Materials*

Kaolinite clay having a specific gravity of 2.43, liquid limit of 54.5% and plastic limit of 44% was used for the entire experiments. The sand used in this study was dry river sand with a specific gravity of 2.61, coefficient of uniformity of 1.8, coefficient of curvature of 1.04 and effective size of 0.28. Geocells were formed using coir geotextile. The properties of geotextile used are given in Table 1.

Table 1. Properties of coir geotextile

Description	Value
Coir board designation	M2R3
Thickness (mm)	7.77
Mass per unit area (gsm)	1267
Opening size (cm x cm)	0.538 x 0.28
Tensile strength (kN/m)	11.28

2.2 *Set-up*

Model tests were conducted in a test bed cum loading frame assembly in the laboratory. Soil beds were prepared in a tank with inside dimensions 1m x 1 m x 1m. Model footing used is of 20 mm thick rigid steel plate having 200 mm x 200 mm size. Footing was loaded with a hydraulic jack supported against the reaction frame. The test set-up is shown in Fig. 1.

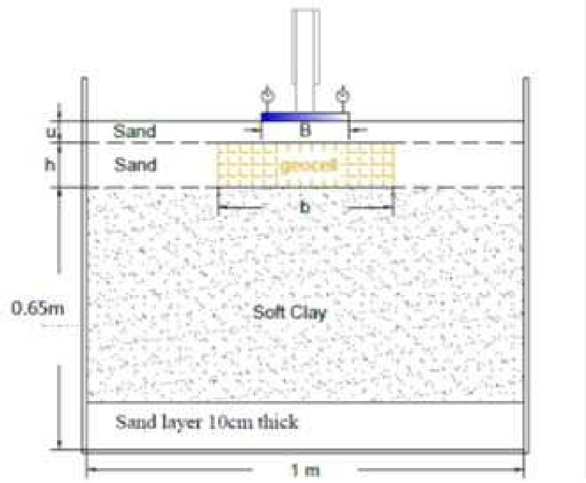

Fig. 1 Test set up

The water content of clay was kept near to its liquid limit so that the soil is used in soft condition. For each layer, the required amount of soil to produce the calculated density was found out and compacted up to the required height. By carefully controlling the water content and compaction, a fairly uniform test condition was achieved throughout the test programme. After placing the geocell mattress in the correct position, the geocells pockets were filled with sand at 70% relative density and a unit weight 15.6 kN/m^3 using sand raining technique.

Four different series of tests were carried out by varying different parameters such as width of geocell mattress (b), height of geocell mattress (h) and pocket size of geocell mattress (d). The height of sand layer above the geocell mattress (u) was kept constant in all the tests as 0.1 times the width of footing as it gives maximum performance [Dash et al., (2001)]. The details of laboratory model tests are given in Table 2.

Table 2. Details of laboratory model tests

Test Series	Type of reinforcement	Details of test parameters
A	Unreinforced	variable parameter: h+u = 0cm,7cm,12cm,17cm, 22cm,27cm constant parameter: ID = 70%
B	Geocell	variable parameter: b= 20cm, 40cm, 60cm, 80cm constant parameter: h=10cm, d=10cm, u=2cm
C	Geocell	variable parameter: h= 5cm, 10cm, 15cm, 20cm, 25cm constant parameter: b=60cm, d=10cm, u=2cm
D	Geocell	variable parameter: d= 5cm, 10cm, 15cm constant parameter: b=60cm, h=20cm, u=2cm

3 RESULTS AND DISCUSSION

3.1 *Effect of width of geocell mattress-test series B*

The bearing capacity improvement factor (If) with respect to 12cm thick sand cushion against foundation settlement ratio (s/B) for test series B, varying the width of geocell, is shown in Fig. 2. For geocell of total width 20 cm, equals to the size of plate (b/B = 1), bearing capacity improvement is found to be less than that of 12 cm thick sand layer. Bearing capacity increases with increase in total width of geocell. The improvement is found to be marginal when (b/B) ratio is more than 3. Hence the ideal situation has been taken as b equal 3B, i.e., the total width of the geocell is 60 cm. The improvement factor becomes almost asymptotic after 15% of foundation settlement. The bearing capacity has been increased by about 1.80 times that of 12 cm sand cushion alone. The increase in bearing capacity with 3B size of geocell was found to be 4.90 times that of soft soil alone.

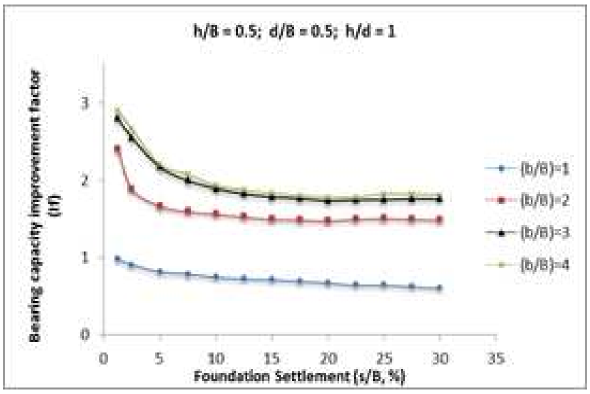

Fig.2 BC improvement factor with foundation settlement for test series B

Geocell made from synthetic geogrid has shown an increase in I_f of about 3 times that of sand cushion bed of equivalent size as reported by Dash et al., (2003) However, it can be noted that geocells made from geogrid gives the above performance when the total width of geocell is 4 times that of loading plate. In the case of geocell made of coir, the increase in I_f by 1.80 times is achieved with geocells having a total width of 3 times that of loading plate. Even though such a difference has been noticed between synthetic and natural fiber geocells, a clear comparison has its own limitations owing to the difference of soft clay bed used in both studies.

The settlement and heave of the clay bed from the centre line of loading plate for various width of geocell are shown in Fig. 3.

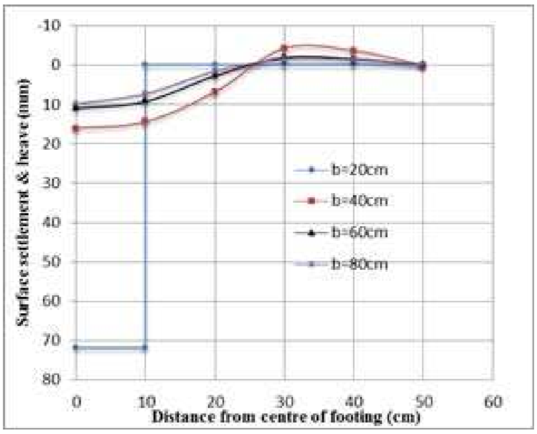

Fig. 3 Settlement and heave of clay bed at 20 kPa - Test series B

As the total width of geocell increases the settlement and heave decreases. The decrease in settlement and heave between the 60 cm and 80 cm wide geocell is found to be marginal. From the above results, the total width of geocell was fixed as 60 cm for further studies.

3.2 *Effect of height of geocell mattress-test series C*

In this series the height of geocell has been varied from 5 cm to 25 cm with a sand cushion of 2 cm above the geocell and load test was conducted. The bearing capacity improvement factor with respect to corresponding sand layer thickness against foundation settlement ratio for test series C is shown in Fig.4.

From Fig. 4 it can be observed that as the height of geocell increases the bearing capacity improvement factor also increase till the height of geocell (h) is 20 cm, i.e, h/B equal to 1 and h/d equals 2. The maximum improvement for 20 cm height geocell at 15% settlement was found to be 2.6 times with that of 22 cm thick sand layer and about 10.5 times with that of clay layer alone. As per Sitharam et al., (2007) and Dash et al., (2001a), the carrying capacity of the soft soil has been increased by 4.8 times and 8 times that of the unreinforced soil.

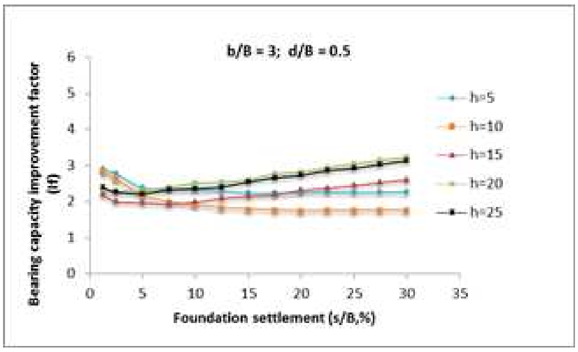

Fig. 4 BC improvement factor with foundation settlement for test series C

The settlement and heave of the clay bed from the centre line of loading plate for various height of geocell are shown in Fig. 5.

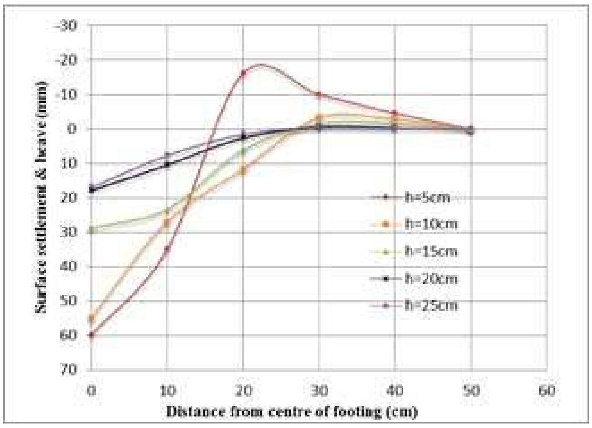

Fig. 5 Settlement and heave of clay bed at 50 kPa - Test series C

From the figure, it can be seen that surface heaving and settlement reduces with increase in height of geocell mattress. The settlement and heave effect seems to be similar for 20 and 25 cm height of geocell. Hence, the optimum height of coir geocell is fixed as width of loading plate. In the case of synthetic geocell, the optimum obtained was 2 times the width of loading plate [Dash et al., (2003)].

3.3 *Effect of pocket size of geocell mattress-test series D*

From the above two series of testing the coir geocell size has been fixed as follows; total length and width of 60 cm, height of 20 cm. In this series the size of pocket has been changed keeping the other parameters constant. The bearing capacity improvement factor with respect to 22 cm thick sand cushion against the settlement ratio is given in Fig. 6.

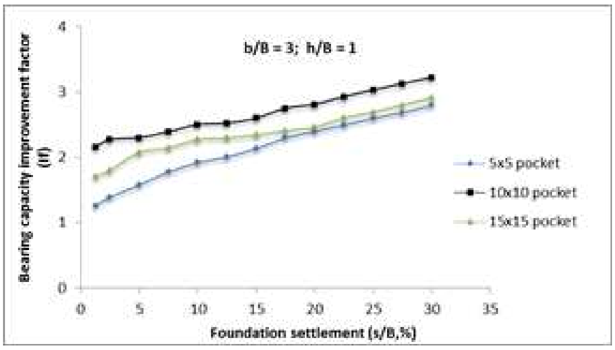

Fig. 6 BC improvement factor with foundation settlement for test series D

The bearing capacity improvement factor found to increase as the pocket size increases from 5 x 5 cm and reaches a maximum at 10 x 10 cm, i.e, d equal to half the size of loading plate (0.5B). In the case of synthetic geocells it has been reported as 0.8 B.

The settlement and heave of the clay bed from the centre line of loading plate for various pocket size of geocell are shown in Fig. 7.

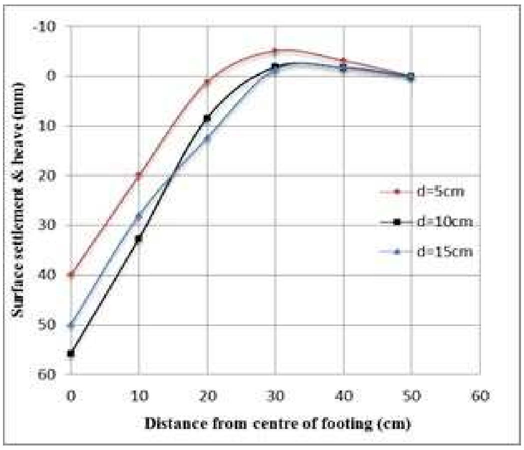

Fig. 7 Settlement and heave of clay bed at 120 kPa - Test series D

From the figure it can be noted that the surface heave is found to be minimum for geocell having 10 cm pocket size. Hence the ideal size of coir geocell can be fixed as follows; length, 60 cm; width, 60 cm; cell size of 10 x 10 cm and height 20 cm. In all the above cases, no failure of geocell was observed even upto a settlement of 30% of footing width.

The carrying capacity of soft soil can be increased by 10.5 times with coir geocell of 60cm x 60cm x 20cm having a cell size of 10cm x 10cm.

4 CONCLUSIONS

From the experimental programme, the following conclusions were made;

The bearing capacity improvement factor increases with increase in height of sand layer. When the size of geocell mattress equal to size of loading plate, bearing capacity of soil reduces compared to the unreinforced soil. The performance increases when the size of geocells mattress becomes greater than the size of loading plate. The optimum width of geocell mattress is equal to 3 times the width of loading plate as against to 4 times as reported for synthetic geocell. The bearing capacity improved by 5 times that of clay bed alone. Surface heaving and settlement reduces with increase in width, height and pocket size of geocell mattress. The height of geocell influences the bearing capacity of soil and it is improved by 10.5 times that of clay bed alone when it is provided with a geocell mattress of height equal to the width of footing. The optimum height of geocell mattress is equal to the width of loading plate as against to 2 times as reported for synthetic geocell. The optimum pocket size obtained is equal to half the width of footing. The carrying capacity of soft soil can be increased by 10.5 times with coir geocell of 60cm x 60cm x 20cm having a cell size of 10cm x 10cm.

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