ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 23, April 2016

INCREMENTAL CYCLIC LOADING ON RING AND CIRCULAR FOOTING RESTING ON GEOCELL REINFORCED SANDY SOIL

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ABSTRACT: Ring footings are widely used as foundation for water tanks, television antennas, silos, chimneys, oil storage tanks etc. This paper presents an experimental study to investigate the cyclic as well as static behavior of model ring footing and circular footing resting on reinforced sandy soil. Coir geocell is used as soil reinforcement. The studies have shown that, with the provision of geocell reinforced sand cushion, there is substantial reduction in settlement of both ring and circular footings due to modified stress distribution. The beneficial effect in terms of increased bearing capacity and reduced settlement is related to the width and depth of placing geocell mattress.

INTRODUCTION

The bearing capacity of shallow foundations besides the parameters and conditions of the soil below the foundation depends on the shape of the foundation. Ring footings are generally used to support columns or walls of axisymmetric structures which are normally circular in plan. It is used as foundation for water towers, transmission towers, television antennas, silos, chimneys and oil storage because it provides a more suitable and cost effective design. The use of ring footing decreases the amount of materials used and it is more economical. The footings of water tanks, oil storage etc may be subjected to cyclic loading as well.

The improvement of bearing capacity of soil may be undertaken by a variety of ground improvement techniques including stabilisation of soil or the introduction of reinforcement. Introducing reinforcement inclusions within the soil is an effective and reliable method in order to improve the engineering properties of soil. 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. 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. Nowadays natural material is introduced as reinforcement to improve the engineering properties of soil. Coir is a natural fiber extracted from husk of coconut. Several studies have been reported on stabilisation of soil using coir fiber. This study presents a series of laboratory results on the behavior of ring and circular footings placed on sand reinforced with coir geocells.

LITERATURE REVIEW

Various researchers have studied the behavior of ring footings experimentally ([1], [2], [3]) and found that for ring footings the improvement in bearing capacity ratio was maximum for an inner to outer diameter ratio of 0.39.Laboratory model test of bearing pressure of circular and ring footings on sand shows that ring footing with an optimum inner to outer diameter ratio of 0.4 at which the bearing capacity will be greater than the circular footing [4].Several investigations have been reported on the use of synthetic geocells to improve the bearing capacity of weak soils ([5],[8],[9],[10]). It has been found that geocell enhances the footing performance on sand and it was also found that optimum width of geocell mattress is around 4 times the width of footing .Studies also shows that in order to obtain the maximum benefit, the top of geocell mattress should be at a depth of 0.1 times the diameter of footing. Cyclic loading on geocell reinforced foundations exhibit a four- fold increase in bearing capacity of footing compared to unreinforced case ([6], [7]).

The main objective of the present study is to model and study the effect of geocell reinforcement on bearing capacity of ring footing and circular footing under vertical loading and cyclic loading using experimental approach. The specific objectives include investigating the effect of geocell width, depth of placing reinforcement on bearing capacity of both footings.

MATERIALS USED

The sand used in the study was collected from Pattambi region, Palakkad. The specific gravity of the soil particles was determined by Pyconometer method and a value of 2.67 was obtained. The maximum and minimum unit weights dry unit weights were found to be 18.4 kN/m^3 and 15.3 kN/ m^3. The particle size distribution was done by the principle of grain size analysis and dry sieve analysis was performed. The Uniformity Coefficient (Cu) and Coefficient of Curvature (Cc) were obtained as 2.87 and

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0.86. From the values obtained, it can be concluded that the sand is poorly graded and it comes under the group SP as per Indian Standard Classification System (ISCS).The gradation curve is shown in figure 1.

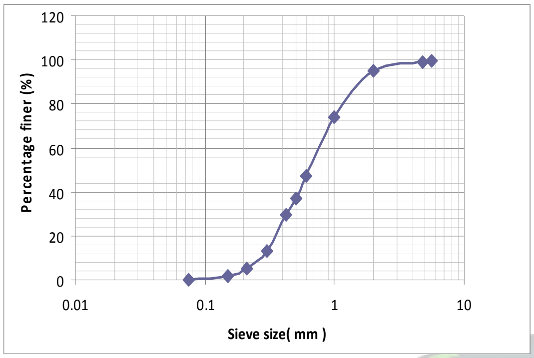

Fig 1: Gradation curve for sand

Table 1 Properties of sand

Description	Value
Specific gravity	2.67
Effective size, D_{10}	0.27
Coefficient of uniformity (Cu)	2.87
Coefficient of curvature (C_C)	0.86
Angle of internal friction	40°

Table 2 Properties of coir geocell

Description	Value
Thickness (mm)	8.88
Mass per unit area (gsm)	1267
Pocket size (cm x cm)	8 x 8
Tensile strength (kN / m)	15.8
Geocell height (cm)	10

LABORATORY MODEL TESTS

Model Box and Footing

The experimental model tests were conducted in a test tank that had dimensions 1m×1m in plan and 0.8m in depth. As per provision of IS 1888-1962, the width of the test pit should not be less than 5 times the width of the test plate, so that the failure zones are freely developed without any interference from sides. The tank was made of steel. The load was applied by means of a hydraulic jack over which proving ring is connected in order to measure the applied load. A dial gauge is provided for the measurement of corresponding settlements. The schematic representation load set up is shown in Fig.2

Model ring footing made of mild steel with an outer diameter of 150mm and inner diameter of 60mm.Model circular footing having diameter same as the outer diameter of ring footing was made from mild steel. The inner to outer diameter ratio of the ring was 0.4. The thickness of model ring and circular footing was 15mm. The ring was placed on the correct middle of the test tank on the soil surface. Four steel columns welded to a circular plate of 15mm thick placed over the surface of footings in order to simulate the over head structures on footing.

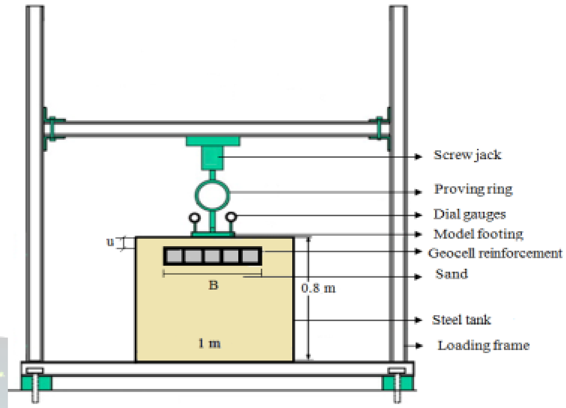

Figure 2: Schematic representation of load set up

Set- up

An experimental program was carried out to study the behavior of ring footing and circular footing resting on both unreinforced and reinforced sand. A relative density of 50% was chosen for the soil medium, to carry out the tests, based on which the density of soil medium was determined. Density corresponds to 50 % relative density is obtained as 16.7kN/m^3. To achieve reasonably homogeneous sand beds of reproducible packing, fixed density method was used to deposit sand in to model box. In this method, sand is filled in the tank with layers of equal thickness, 100 mm. Total depth of complete sand mass was kept equal to 7.5 cm. For each layer, mass of sand required to achieve the density was calculated. That total mass in each layer was filled by applying proper compaction.

First the bearing capacity test for unreinforced soil was conducted. After filling the sand at particular depth, ring footing was placed. Then the loading is provided by means of a hydraulic jack placed over the ring footing with a support of loading plate. The load was applied in small increment until a settlement of one-tenth of the outer diameter of the ring footing is used. The settlement of the footing was measured using dial gauges. Similarly the bearing capacity of unreinforced soil with circular footing

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is determined. The test set up is shown in Fig 3.

Figure 3: Test set up

After that geocell reinforcement was introduced, this is shown in figure 4. After placing the geocell mattress in correct position, geocell pockets are filled with sand at relative density of 50% and having a unit weight of 16.7 kN/m^3.The pocket size of geocell and height of geocell mattress were kept constant in all test.

Figure 4: Coir geocell mattress filled with sand

A total of 5 series of experiment were carried out on model footings. Series 1 consists of bearing capacity test on ring footing and circular footing without reinforcement under static loading. Series 2 consists of bearing capacity test on ring and circular footing under cyclic loading. Series 3 consist of bearing capacity test on ring and circular footing with coir geocell of varying width under static loading. Series 4 consists of bearing capacity test on ring footing and circular footing with coir geocell placed at different depth under static loading. Series 5 consists of bearing capacity test on ring and circular footing with optimum width (B) and depth of placing geocell (U) under static loading. Series 6 consists of bearing capacity test on ring and circular footing with optimum width and depth of placing geocell under cyclic loading.

RESULTS AND DISCUSSIONS

A total of 30 tests were carried out on the model ring and circular footing supported on unreinforced and reinforced soil. The effect of coir geocell width and depth of placing geocell mattress on bearing capacity of ring and circular footing under static and cyclic loading is investigated.

Static and cyclic test on unreinforced soil bed

From the bearing capacity tests performed, the load settlement behavior is found out. First the unreinforced case is found out for both ring and circular footings. From the load settlement graphs it is found that the type of shear failure is local shear failure. In local shear failure there is a significant compression of the soil under the footing and only partial development of state of plastic equilibrium. Due to this reason, the failure surface does not reach the ground surface and only slight heave occurs. The load settlement graph for unreinforced case is shown in figure 5 and 6. From the figure, it can be seen that ring footing with an inner to outer diameter ratio of 0.4 has greater bearing capacity as compared to that of circular footing with same outer diameter under static and cyclic loading. This may be due to the interaction between the failure wedges forming beneath the ring footing. In case of cyclic loading, in each stage due to unloading, a small amount of settlement rebounds which named elastic or recoverable settlement (the amount of elastic rebound of the soil increases with increase in the stress level) while a major part of the settlement is plastic settlement and remains in the system.

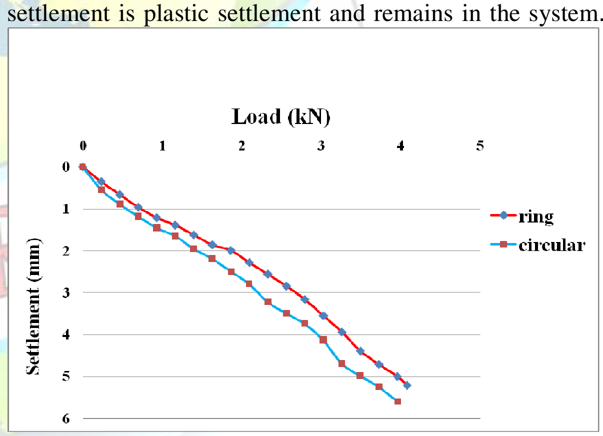

Figure 5: Load settlement behavior of ring and circular footing for reinforced case under static loading

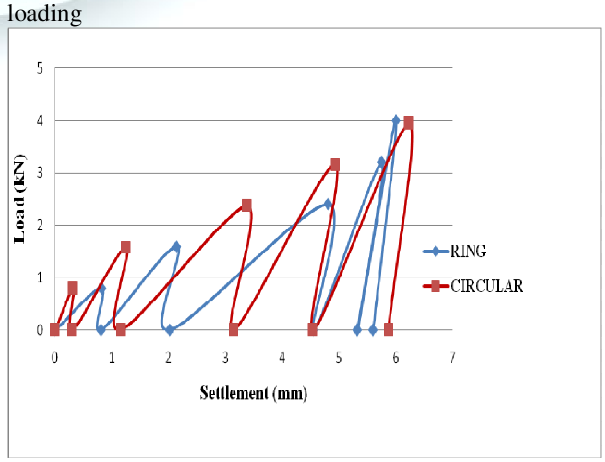

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Figure 6: Load settlement behavior of ring and circular footing for reinforced case under cyclic loading.

Effect of width of geocell

The load settlement response of geocell reinforced soil by varying total width of geocell mattress with respect to unreinforced soil in case of both ring and circular footing is compared in figure 7 and 8. From figure, it is clear that, in case of both footings, if the size of geocell mattress equal to the size of footing, the bearing capacity of soil is almost same as unreinforced case. Figure shows that in case of both ring and circular footing, performance increases as the geocell mattress size is more than the footing size. Also there is no significant improvement when geocell mattress size changes from 60 cm to 75 cm. By providing geocell reinforcement of width 60 cm x 60 cm at a U/B ratio of 0.25 provides an increase of 69% and 56% in bearing pressure of ring and circular footings.

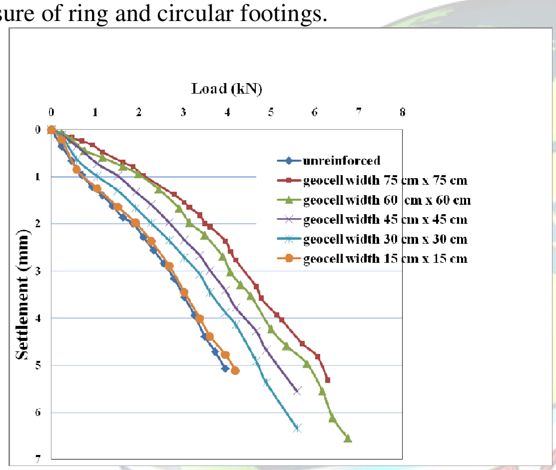

Figure 7: Load settlement behavior of ring footing for varying width of geocell

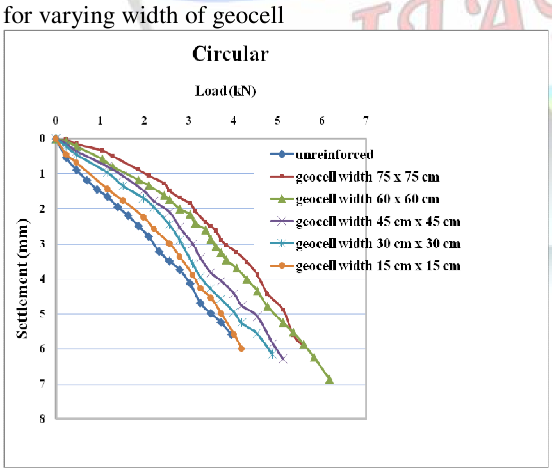

Figure 8: Load settlement behavior of circular footing for varying width of geocell

Effect of U/B on bearing capacity

The load settlement curves for varying depth of placement of geocell reinforcement in case of ring and circular footings is shown in 9 and 10.It can be seen that, the load v/s footing settlement response of reinforced sand bed is far better than the un-reinforced case. The footing resting on the soil-reinforcement composite will carry more loads. This shows that strength improvement is totally depends on the position the reinforcement within the sand bed. The response of the reinforced sand bed is seen to improves at a depth ratio U/B=0.1 and 0.25 in case of circular and ring footing respectively.

Static and cyclic test on reinforced soil bed

In case of ring footings, bearing capacity increases by 69% by providing geocell of width 60 cm x 60 cm at a U/B ratio of 0.25. In case of circular footings, bearing capacity increases by 73.5% by providing geocell of width 60 cm x 60 cm at a U/B ratio of 0.1 under static loading. Comparing the settlement values corresponding to maximum cyclic load in unreinforced case, settlement value decreases.

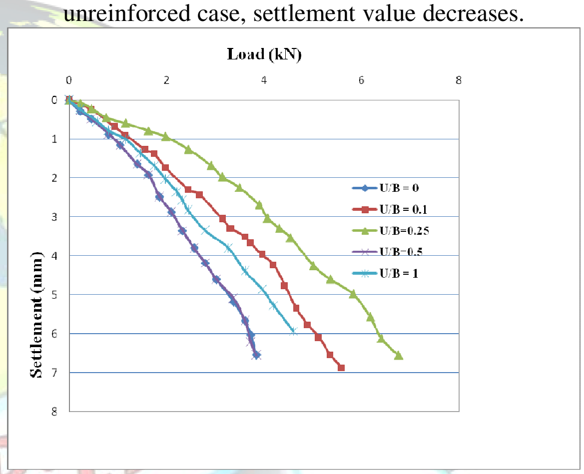

Figure 9: Load settlement behavior of ring footing for varying depth of geocell of 60 cm x60 cm wide

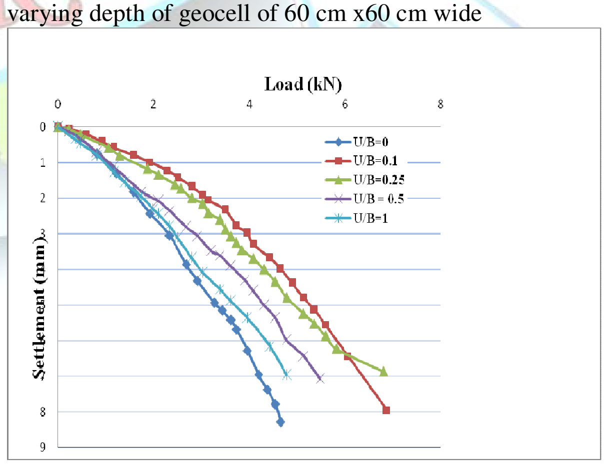

Figure 10: Load settlement behavior of circular footing for varying depth of geocell of 60cmx60 cm wide

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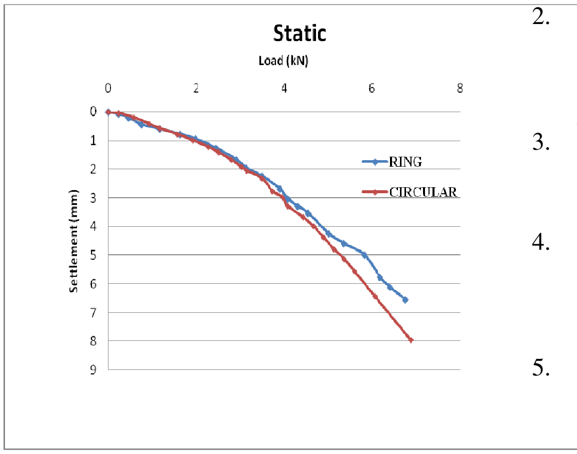

Figure 11: Load settlement behavior of ring and circular footing with optimum depth and width of geocell under static loading.

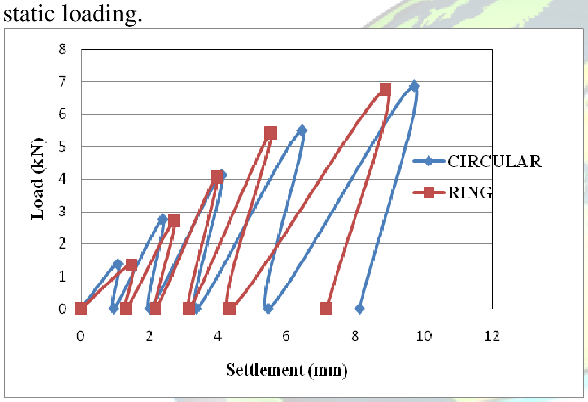

Figure 12: Load settlement behavior of ring and circular footing with optimum depth and width of geocell under cyclic loading

CONCLUSIONS

From the experimental programme, the following conclusions were made:

The bearing capacity of ring footing with inner to outer diameter ratio of 0.4 is greater than that of circular footing in static and cyclic case. The optimum width of geocell mattress is equal to four times the diameter of footing in case of both ring and circular footing. Surface heaving and settlement reduces with increase in width of geocell. The optimum depth of placing coir geocell is obtained as 0.1 times the diameter of footing in case of circular and 0.25 times the outer diameter in case of ring footing. The results shows that footing performance due to cyclic loading is better for geocell reinforced soil than that of unreinforced soil.

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