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BEHAVIOUR OF RING FOOTING ON GEOSYNTHETIC REINFORCED SAND

S. Sona, M.Tech. Student, Thejus Engineering College, Vellarakkad, sonasuresh19@gmail.com
J. Soumya, Assistant Professor, Thejus Engineering College, Vellarakkad, soumyacjd@gmail.com

ABSTRACT: Laboratory model test was conducted on model ring footings of size 100mm outer diameter and having inner diameters 20mm, 40mm and 60mm made of mild steel in a mild steel test box of size 500mm x 500mm x 600mm. Test was conducted on unreinforced and geotextile reinforced bed to determine optimum top layer spacing and optimum number of geotextile layers. The load – settlement behaviour of rings indicate that the optimum top layer spacing is 0.3 times the outer diameter of ring and optimum number of reinforcement layer is 3. The study also highlights the improvement of bearing capacity ratio.

INTRODUCTION

Nowadays, ring footings are often used for the foundation of axisymmetric structures having circular shape in plan. They are generally used as the foundation of storage tanks, telecommunication towers, bridge piers and chimneys. They are also used for large and tall structures to resist lateral loads and to increase the stability against overturning. Use of reinforcements in the foundation material improves the behaviour of foundation as well as enables the poor quality foundation materials to be used as structural components. Also assessing suitable depth of reinforcement avoids unnecessary large excavations which is economical and safe.

LABORATORY MODEL TEST

Footing and Test Box

Model footings made of mild steel were used for the study. Three numbers of ring footings with outer diameter 100 mm and inner diameters of 20mm, 40mm and 60 mm were made and the corresponding radius ratios were 0.2, 0.4 and 0.6 respectively. The thickness provided for the ring footing was 10 mm. the rings were provided with four columns welded to its surface to simulate the structure over the footing and a circular platform of mild steel with thickness 3 mm was welded to the top of these columns for the even distribution of load to the footing.

The test was conducted in a test box made of mild steel. The test having dimension 500mm x 500mm x 600mm and having a thickness of 3 mm was used. According to IS 1888-1962, the width of the test pit should not be less than five times the width of the test plate for the failure zones to be freely developed without any interference from the sides. Inside portion of the test box was painted to minimize the boundary effects. A loading frame was also welded to the top of the test box for connecting the loading systems.

Test Material

Sand was used as the foundation material for the study. The sand for the test was collected from Bharathapuzha region in Palakkad District and it was sun dried. The specific gravity of the sand was determined by using pycnometer method and the particle size distribution of sand was determined by dry sieve analysis. The particle size distribution curve is shown in the fig.1.

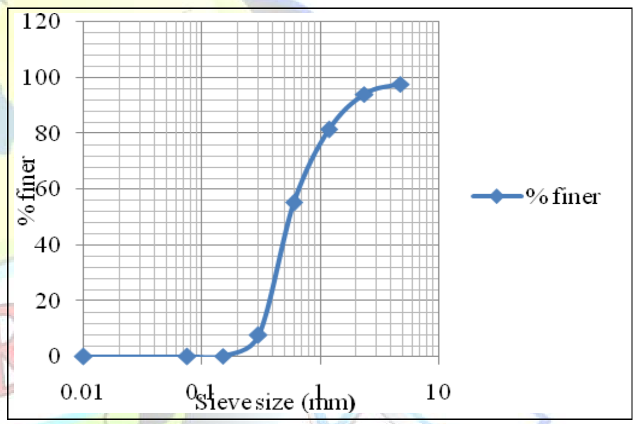

Fig.1 Particle size distribution curve of sand

The shear parameters of the material were determined by using direct shear test by filling the sand in the shear box at a particular density. The maximum and minimum dry densities and the corresponding minimum and maximum void ratios were determined. Sand properties are shown in Table 1.

Table 1 Properties of sand

Property	Value
Effective Size (D10)	0.32mm
Uniformity Coefficient (Cu)	2.125
Coefficient of Curvature (Cc)	0.87
Fine Gravel	5.55%
Coarse Sand	41.25%
Medium Sand	52.75%
Fine Sand	0.45%
Specific Gravity	2.64
Cohesion (C)	0
Angle of Internal Friction (φ)	50°

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Maximum Dry Density	16.9 kN/m^3
Minimum Dry Density	15.1 kN/m^3
Maximum Void Ratio	0.71
Minimum Void Ratio	0.53

The results concluded that the sand is poorly graded medium sand. As per Indian Standard Classification System, it comes under the group of poorly graded (SP).

Reinforcement

Geotextile was used for providing reinforcement to the sand bed. The geotextile used was polypropylene woven fabric of GF 04 series. The properties of geotextile are shown in the Table 2.

Table 2 Properties of geotextile

Property		Value
Fabric Size		250cm
Tensile Strength	Warp	195kgf
	Weft	198kgf
Elongation	Warp	24%
	Weft	25%
Weight		177g/m2
Mesh	Warp	10 No. per inch
	Weft	10 No. per inch
Colour		Milk White
Amount of Polypropylene		96%
Amount of Filler		2%
Amount of UV		1%
Amount of White Master Batch		1%

EXPERIMENTAL SETUP AND TEST PROGRAMME

Experimental programme was conducted to find out the behaviour of ring footing on reinforced and unreinforced sand bed. The sand was filled in the test box as layers up to a height of 50cm. The height of the bed was determined such that it should not be less than five times the outer diameter of the footing. Raining technique was used to fill the tank to get homogeneity of the sand layers. In this method, sand was allowed to discharge from a particular height at a constant discharge rate and test box was filled in dense condition. The ring footings are placed at the middle of the box and the constant uniform settlement was applied to the footing by means of a screw jack arrangement system. The settlements are measured using dial gauge and the corresponding load was measures from the proving ring arrangement. The experimental setup is shown in fig.2.

A total of 3 series of tests were conducted on the rings. Series 1 consists of testing the bearing capacity of the three footings on unreinforced sand bed. Series 2 consists of bearing capacity test on three footings with a single layer of reinforcement at different depths in the sand bed. Series 3 consists of testing the bearing capacity of three rings by increasing the number of geotextile layers. Series 2 was conducted to determine the optimum top layer spacing of the geotextile reinforcement and series 3 was conducted to determine the optimum number of reinforcement layers.

Fig.2 Experimental setup

RESULTS AND DISCUSSION

A total of 30 tests were conducted on the footings both on unreinforced and reinforced sand bed. The factors determined are the optimum radius ratio for the footing, optimum top layer spacing of reinforcement, and optimum number of reinforcement layers. The improvement in the bearing capacity was expressed in terms of Bearing Capacity Ratio (BCR) which is a dimensionless factor. Bearing capacity ratio is the ratio of bearing capacity of reinforced soil to the unreinforced soil.

The load – settlement behaviour of three footings on unreinforced sand bed was determined first. The optimum top layer spacing for rings was determined by using a single layer of reinforcement placed at depths 0.1D, 0.2D, 0.3D, 0.4D etc. where D is the outer diameter of the footing. Then the behaviour of three rings on the inclusion of multiple layers of reinforcements was determined. In this test, the top layer was fixed at the optimum top layer depth and further layers are included below the first layer at a spacing of the optimum top layer.

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From the load – settlement graph obtained, it was found that the shear failure type is general shear failure. Continuous, well defined and distinct failure surface was developed between footing and ground surface. Continuous bulging of shear mass adjacent to footing was visible and failure was sudden and catastrophic with pronounced peak in the curve. The length of disturbance beyond the edge of footing was large and the state of plastic equilibrium was reached initially at the footing edge. The load – settlement behaviour of footings on unreinforced sand bed is shown in the fig.3.

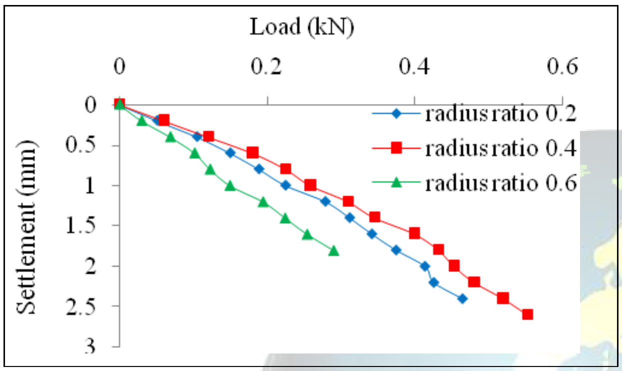

Fig.3 Load – Settlement behavior of rings with radius ratio 0.2, 0.4 and 0.6 on unreinforced sand bed

OPTIMUM TOP LAYER SPACING OF REINFORCEMENT

The bearing capacity of footing changes with the depth of top layer of footing. At optimum depth the beating capacity become maximum value and decreases for further increase in depth. The load – settlement behaviour of rings with top layer at different depths are as shown from fig.4 to fig.7.

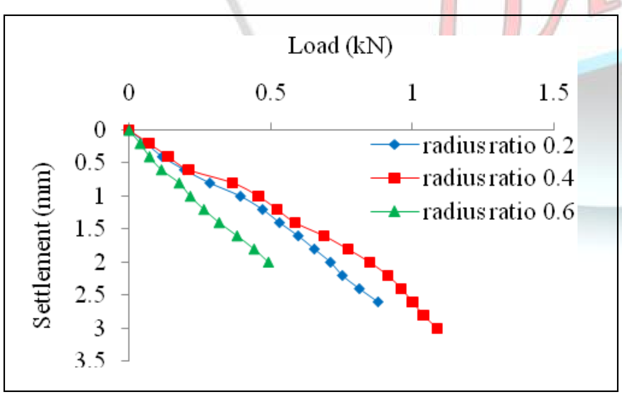

Fig.4 Load – settlement behavior of rings on sand bed with geotextile at 0.1D depth

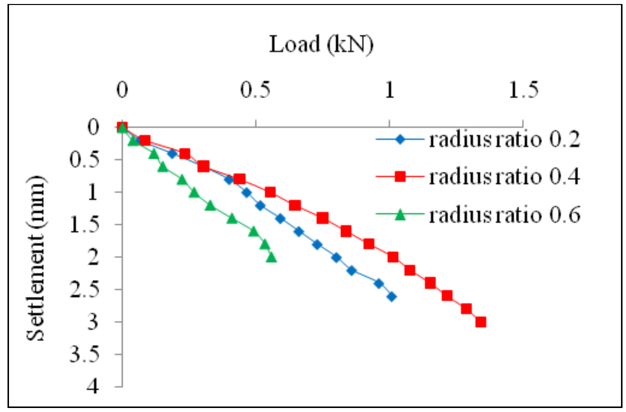

Fig.5 Load – settlement behavior of rings on sand bed with geotextile at 0.2D depth

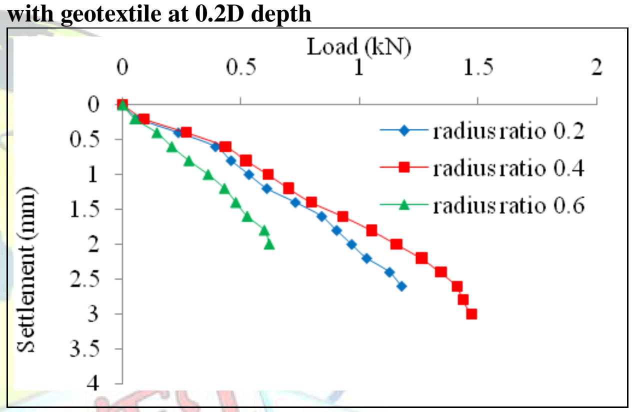

Fig.6 Load – settlement behavior of rings on sand bed with geotextile at 0.3D depth

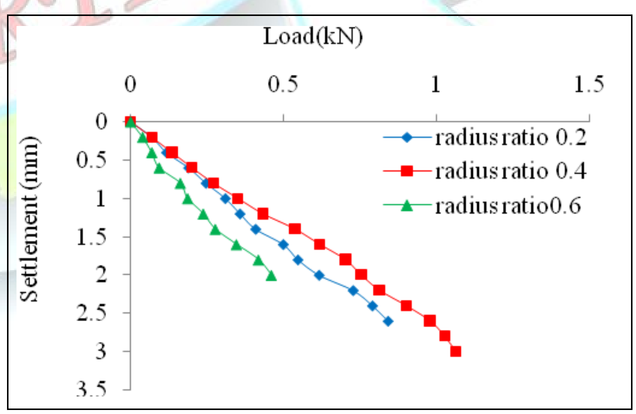

Fig.7 Load – settlement behavior of rings on sand bed with geotextile at 0.4D depth

The bearing capacity of all rings increased for the reinforcement up to a depth of 0.3 times the outer diameter of the ring. The bearing capacity improvement of the rings is as shown in fig.8.

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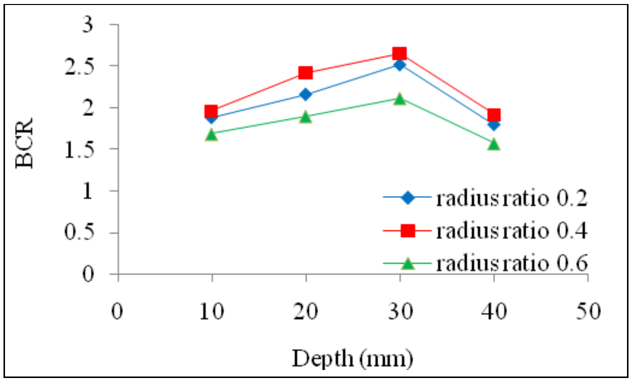

Fig.8 Bearing capacity improvement of ring footings for various depths of geotextile

OPTIMUM NUMBER OF REINFORCEMENT LAYERS

The bearing capacity of footing generally increases with increase in the number of reinforcement layers up to a particular number beyond which further increase in the number of reinforcement layers does not cause any improvement in the bearing capacity. The load – settlement behaviour of rings for each increment of reinforcement layer are as shown from fig.9 to fig.13.

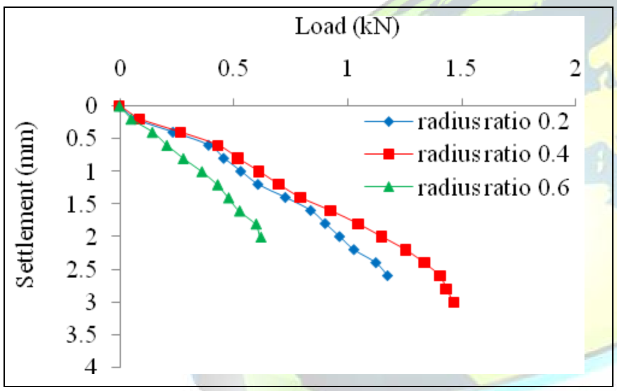

Fig.9 Load – settlement behavior of rings on sand bed with one layer of geotextile

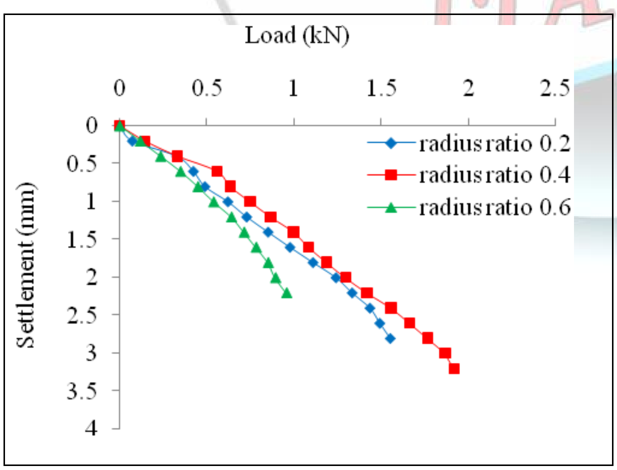

Fig.10 Load – settlement behavior of rings on sand bed with two layers of geotextile

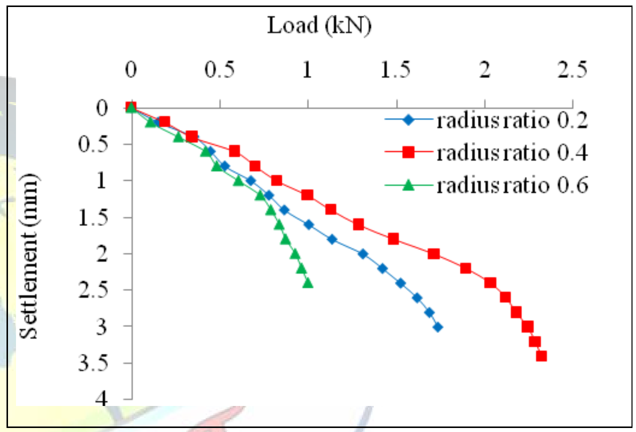

Fig.11 Load – settlement behavior of rings on sand bed with three layers of geotextile

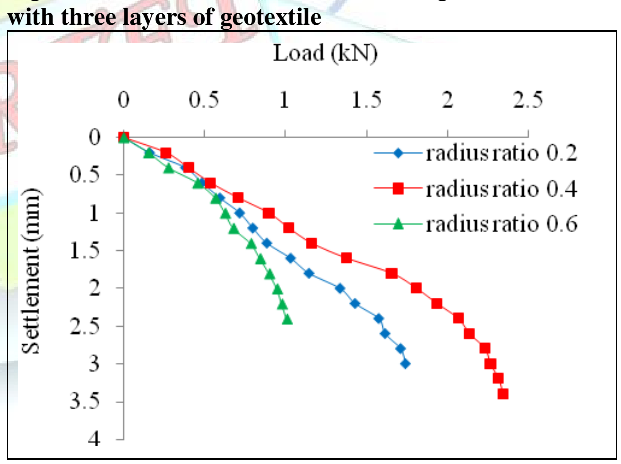

Fig.12 Load – settlement behavior of rings on sand bed with four layers of geotextile

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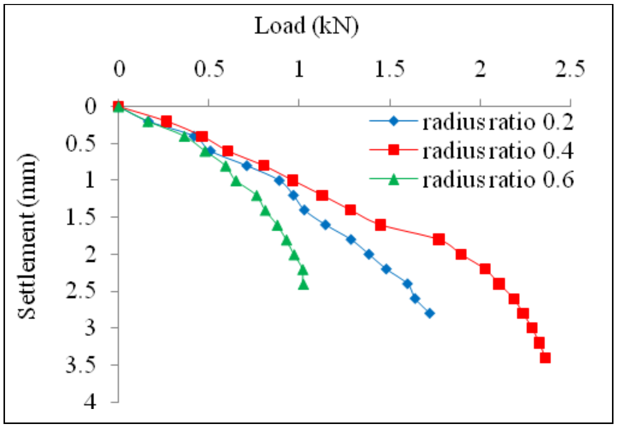

Fig.13 Load – settlement behavior of rings on sand bed with five layers of geotextile

The bearing capacity of ring footing increased up to three layers of reinforcement for all radius ratios and there was no considerable improvement in bearing capacity after the third layer. The bearing capacity improvement is as shown in fig.14

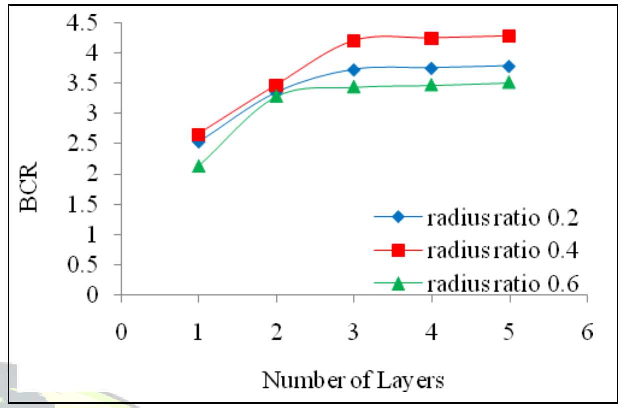

Fig.14 Bearing capacity improvement of ring footings for number of reinforcement layers

CONCLUSIONS

From the study conducted it was found that the synthetic woven geotextiles can be effectively used for bearing capacity improvement for cohesion less soils such as sand. The various findings from the study are listed below.

- The mode of shear failure was general shear failure which is common in the case of foundation bed of dense condition.
- The maximum bearing capacity was attained for ring of radius ratio 0.4 in unreinforced as well as reinforced cases.
- The optimum top layer spacing of the reinforcement layer is 0.3 times the outer diameter of the footing. The maximum bearing capacity was obtained for radius ratio 0.4 and the bearing capacity improvement noticed was 265.7%.
- The optimum number of reinforcement layers was obtained as three for all radius ratios since there was no considerable improvement in the bearing capacity beyond three layers. The ring having radius ratio 0.4 attained maximum bearing capacity and the bearing capacity improvement was 420.1%.

The study can also be conducted using rings of different radius ratios to determine whether it is advantageous or not. Different types of foundation materials can also be considered. Since the experiment is on the model footings, the actual effects on soil in field conditions may vary.

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