PERFORMANCEOFMODEL FOOTINGIN GEOCELL REINFORCEDSAND BED AGAINST PULLOUT

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ABSTRACT: The study reported in this paper deals with the performance of model circular footing in geocell reinforced bed with and without basal reinforcement against pullout load. A circular footing model with diameter, D = 100 mm was embedded at a height of 200 mm in medium dense sand bed (RD=54%) and tested by applying rate of pull of 0.01 mm/s. Geonet having tensile strength of 7.81 kN/m was used for making geocells. The width of the geocell was adopted as 2D and its thickness was varied as 0.25D, 0.5D and 0.75D. The increase in uplift capacity of model footing in geocell reinforced sand bed was 170% and the inclusion of additional planar layer of geonet (basal reinforcement) beneath the geocell enhanced the resistance further by of 30% i.e. the increase in the capacity was 200% over the capacity of footing in unreinforced sand bed. Hence the inclusion of geocell with and without basal reinforcement in sand enhanced the uplift capacity considerably. However the increase in pullout resistance was found to be marginal for the thickness of geocell more than 0.5D.

KEYWORDS: Geocell, Basal reinforcement, circular footing, uplift

INTRODUCTION

Generally foundations of tent type structures are subjected to uplift forces. The resistance of the footing against the uplift was offered by the self-weight of the footing and the soil above the footing within the rupture surface. Generally the uplift resistance of the footing was increased by increasing the geometrical features of the footing and depth of embedment. The above methods adopted for increasing the uplift resistance were quite uneconomical. Hence the research works were carried out for more feasible solution to increase the uplift resistance and as a result the inclusion of geosynthetics (Ravichandran et al., 2008; Sivaraman et al., 2014; Khatun and Chottopadhyay, 2010; and Choudhary and Dash, 2013) into the soil-footing system was found to be the better solution. In most of the research works, it was aimed at to enhance the uplift capacity of footings by geosynthetic reinforcement and was included as single or multiple layers; but the effects of geocell reinforcement on uplift capacity was not studied adequately. Therefore the present research work is carried out to study the performance geocell (three dimensional form of geosynthetics) system in increasing the uplift resistance of the footing. Also the effect of inclusion of basal reinforcement beneath the geocell layer was also analysed in this work. The objectives of the research work fulfilled by performing tests on circular model footing embedded in medium dense sand bed with geocell inclusion as reinforcement.

Details of test medium, geosynthetic material, experimental facility developed and procedure adopted for conducting tests are presented in the subsequent sections. Results of 1g model tests

conducted by varying the thickness of geocell with and without basal reinforcement are presented and discussed. Important conclusions drawn from the study are also included in this paper.

PROPERTIES OF MATERIAL

The test materials includes river sand and geosynthetics used for fabricating geocell. The properties of sand and geocell material are presented below:

Sand and Sand Bed

The test medium chosen for the study is a clean river sand. The minimum and the maximum unit weights were found to be 13.60 kN/m^3 and 17.98 kN/m^3 respectively. The specific gravity of the sand was found to be 2.65. It is classified as poorly graded sand (SP) based on Unified Classification System. Tests were conducted in medium dense sand, for which bed was prepared by compaction to achieve the relative density of 54%. The unit weight of the sand bed was 15.66 kN/m^3. The angle of internal friction of the medium sand was found to be 35°.

Geocell Material

The geocell used in this study was fabricated using locally available geonet material. The aperture opening of the geonet was diamond in shape and the opening size was 8 x 6 mm. The tensile strength of the material was found to be 7.7 kN/m at the strain of 20%. The extension was 3.2% for 50% of peak load value. Cylindrical shape geocell was fabricated manually using geonet material with diameter equal to twice the diameter of model foundation with thickness of 0.25D, 0.5D and 0.75D. The geocell thus made contains 24 pockets and the pockets were tied together using geosynthetic ties. Basal reinforcement used in the study was also made of same geonet material.

EXPERIMENTAL ARRANGEMENT

The Fig. 1 shows the experimental arrangement for the pullout tests. A model steel tank of size 740 mm x 740 mm x 650 mm was used to perform the tests. The steel tank was graduated for every 50 mm and was placed in a loading frame of capacity 50 kN. A separate loading yoke arrangement was made to pull the circular model footing of size 100 mm using a hydraulic jack of 100 kN capacity. The jack is operated manually using the hydraulic pump. A proving ring of 2.25 kN capacity was placed in between the loading yoke and the hydraulic jack to observe the mobilised pullout capacity. Dial gauges were placed on the plate connected to yoke to measure the displacement of footing. The travel length of the dial gauges was 50 mm with least count of 0.01 mm.
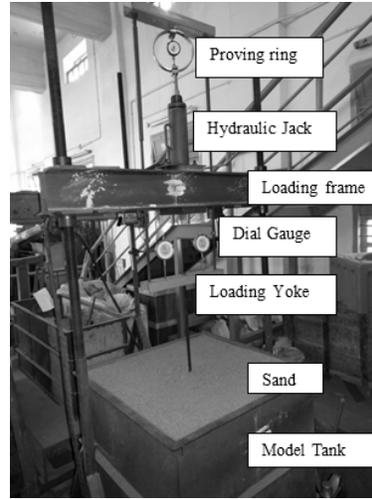
Fig. 1 Experimental arrangement for Pullout tests

The sand bed was prepared to the required density using sand pouring and compaction technique. The tests were conducted on footing embedded at a depth of 2D (=200 mm) from the sand bed surface. Once the desired depth was reached from the bottom of the tank, the footing arrangement which consists of the loading yoke was placed in position and sand was poured above the footing in layers and compacted to achieve required density of bed.

Test was conducted by uplifting the model footing by operating the jack at an approximate rate of 0.01 mm/s. The load and displacement readings were recorded at regular time interval continuously till the displacement of footing was 40mm.
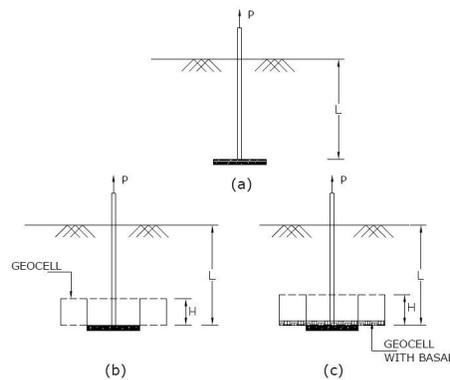

Fig. 2 Model Footing (a) Model Circular Footing, (b) Model Footing with Geocell Reinforcement and (c) Model Footing with Geocell+Basal Reinforcement.

In this research study three series of tests were conducted as shown in Fig. 2. First series of tests were on model footing without geocell inclusion. In the second and third series, tests were conducted in geocell inclusion but without basal and with basal reinforcement respectively.

In tests on reinforced cases the geocell was placed directly above the footing. In the case geocell with basal reinforcement, the basal reinforcement was placed beneath the geocell and tied together using the cable ties. The geocell with basal reinforcement was placed directly above the

footing (Fig. 2). The tests were carried out with both the configurations of reinforcement and compared with the results of unreinforced case to understand the effect of geocell reinforcement of both the configurations and the thickness of the geocell on pullout response.

RESULTS AND DISCUSSION

The pullout tests on the model footings embedded in the medium dense sand were conducted in unreinforced bed, geocell reinforced bed and geocell+basal reinforced sand bed. The results thus obtained are analysed in the following sequence: a) Load-displacement response of the footing in reinforced and unreinforced sand bed, b) Effect of the thickness of the geocell and c) Effect of inclusion of planar/basal reinforcement beneath the geocell.

1.1   Load-Displacement Response of Footing in   Reinforced and Unreinforced Sand Bed
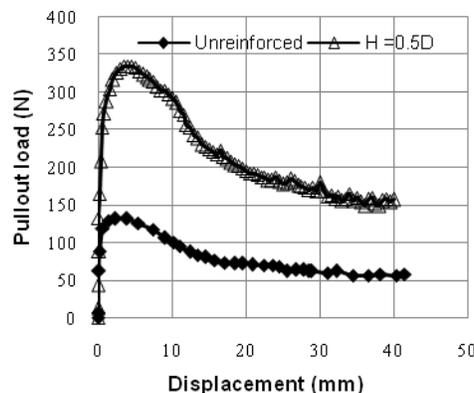

Fig. 3 Pullout response curves in medium dense sand bed

Fig. 3 shows the load response curves of the footing embedded in medium dense sand with and without reinforcement. In the unreinforced sand bed, the circular footing was embedded at 2D depth and the pullout tests were conducted. The load response curves shows three-phase behaviour with distinct pre-peak, post-peak and residual phases as reported by earlier researchers (Ravichandran et al., 2008; and Sivaraman et al., 2014) on anchors embedded in sand with inclusion of single and multi layers of geosynthetic reinforcements. In the pre-peak part of the curve, the pullout response (load) increases rapidly for a small increase in the displacement of footing. Once the peak had reached the resistance tend to decrease gradually. Further in the residual zone, the pullout resistance becomes almost constant value for the increase in displacement. In this case, the peak pullout load was found to be 131 N and the corresponding displacement was found to be 3.8 mm. The residual condition is reached at the displacement of 26mm with the pullout load of 57 N. The load-response curve of the reinforced case is similar in shape to that of the unreinforced case, but with increase in pullout and residual loads. The reinforced case with 0.5D of geocell thickness had contributed in improving the pullout and residual loads to 334 N and 156 N respectively. But the rate of reduction in the pullout load is higher in the post-peak phase of the curve when compared with the unreinforced case. The percentage of improvement was found to be nearly 173%.

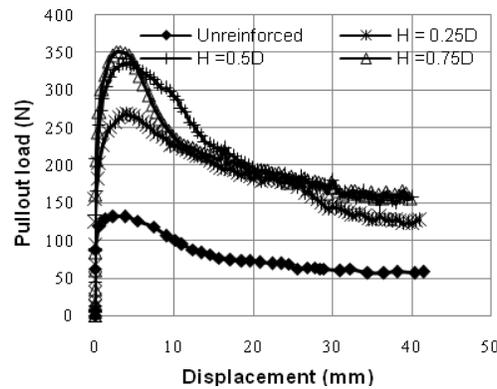### 1.2   Effect of Thickness of the Geocell

Fig. 4 Pullout response curves in medium dense sand bed for varying thickness

Fig. 4 shows the pullout load response curves of the circular anchor tested for the cases of reinforced and unreinforced conditions in medium dense sand bed. In the case of reinforced condition the thickness of the geocell adopted was 0.25D, 0.5D and 0.75D. The peak pullout load (P_u) corresponds to the displacement ($\square$), residual pullout load (R) and the improvement are compared with the unreinforced state (URF) in Table 1. From Table 1 it could be seen that by increasing the thickness from 0.25D to 0.5D there was a significant increase in the peak pullout load. When the thickness of the geocell was further increased (i.e., 0.5D to 0.75D), the increase was insignificant. From the above results, it is understood that the increase in the peak pullout capacity is marginal for the geocell thickness more than 0.5D.

Table 1 Comparison of Peak load and displacement for various thickness of geocell reinforcement with unreinforced condition.

H	P_u (N)	δ (mm)	Improvement (%)	R (N)
URF	131	3.8	-	57
0.25D	267	4	121	126
0.5D	334	3.5	173	156
0.75D	350	2.8	171	155

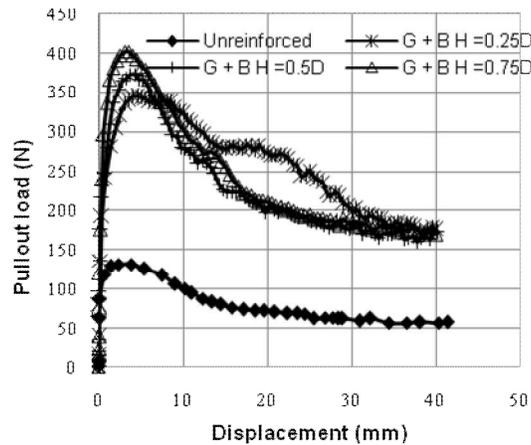**1.3   Effect of Inclusion of Planar/Basal Reinforcement Beneath the Geocell Layer**

Fig 5 Pullout response curves in medium dense sand with geocell+basal reinforcement of varying thickness

The pullout response curves of footing in the medium dense sand bed reinforced with geocell+basal arrangement (G+B configuration) for different thickness of geocell shown in Fig. 5. The load-displacement curves are almost similar to that of the unreinforced and geocell reinforced cases. But due to the inclusion of basal reinforcement at the base of the geocell, the peak pullout load increases by 30%. In the geocell reinforcement, the bottom portion of the reinforcement is left open, hence the sand from the pockets of outer ring flows easily through the bottom.In case of G+B configuration, the basal reinforcement inclusion reduces the free flow of sand through the bottom opening of geocell pockets while pulling the footing, apart from adding stiffness to the geocell-sand reinforcement system, thus increased the pullout capacity.

Pullout resistance of footing for the two types of reinforcement configurations adopted in the present research are compared in Fig. 6 for the thickness of 0.25D, 0.5D and 0.75D. The pullout capacity is increased by the inclusion of basal layer of reinforcement to the geocell. In addition increase in pullout capacity with thickness of geocell is not significant for the geocell with thickness more than 0.5D for the density of sand considered in this study.
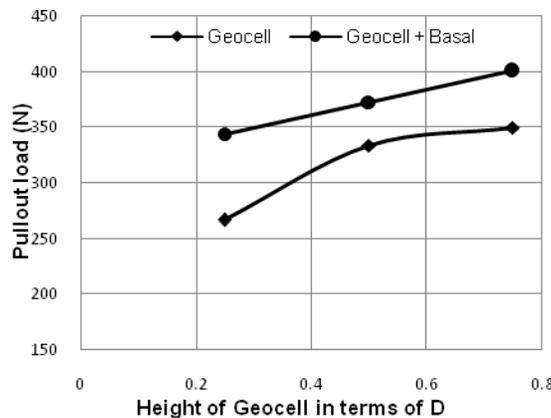

Fig. 6 Comparison of peak pullout loads between the two reinforcement configurations adopted.

CONCLUSION

The provision of geocell improves the pullout capacity of the model footing due to the stiffness of the geocell-soil system. The volume of the rupture surface is increased which increase the weight of the soil mass above the anchor, thus ensuring the improvement in the pullout load capacity. The effect of thickness is less pronounced beyond 0.5D. Addition of the planar layer beneath the geocell contributes reasonably well to the pullout capacity by increasing the stiffness of the system.

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