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Influence of Footing Size on Reinforcement Geometrical Parameters

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Abstract. The load-bearing capacity of the reinforced sand bed depends on the optimum geometrical parameters of the reinforcement layer. This paper presents the effect of size of the footing (D) on optimum geometrical parameters of the reinforcement i.e. placement depth of first reinforcement layer (u) and the vertical spacing between the reinforcement layers (h). The jute geotextile reinforcement layer was used for the present model tests. All model tests were conducted using 50 mm diameter circular footing in a steel tank having an inner dimension of 450 mm x 450 mm x 350 mm. In each test, sand placed at relative density (R_d) of 70%. Finally, the present test results are compared with the plate load tests of jute geotextile reinforced sand beds using footing diameter (D) 150 mm. The size variation factor for two different diameters (D) of footings is 3. The test results shows that the values of optimum geometrical parameters of the reinforcement are not much varying with respective size of the footing (D). In comparison, the variation with respective size of the footing is relatively higher for optimum vertical spacing of the reinforcement (h) than the optimum placement depth of first reinforcement layer (u).

Keywords: Jute geotextile, Footing Size, Reinforcement geometrical parameters.

1 Introduction

Due to increase in the demand for the land for constructions, it is necessary to improve the soil load-carrying capacity by applying low cost ground improvement techniques. The soil reinforcement technique using geosynthetics plays a major role in improving the soil load-bearing capacity in an economical way in comparison to other ground improvement techniques. In literature, several researchers performed a number of experimental and numerical studies using different types of geosynthetics such as geotextiles, geogrids and geocells. Based on the experimental findings, it was concluded that the improvement of soil load-carrying capacity depends on the optimum geometrical parameters of the reinforcements such as placement depth of topmost reinforcement layer from the footing base (u), the vertical spacing between the reinforcement layers (h), number of reinforcement layers (N), and size of the reinforcement layer (B_r) e.g. Binquet and Lee (1975a, b), Guido et al. (1986), Yetimoglu et al. (1994), Sitharam and Sireesh (2004), Dash et al. (2004), Ghosh et al. (2005), Basudhar et al. (2007), Latha and Somwanshi (2009), Naderi and Hataf (2014), Tavangar and Shooshpasha (2016), and Buragadda and Thyagaraj (2019).

Literature shows that the studies on effect of footing size on optimum geometrical parameters of the reinforcement are limited (Omar et al. 1993b; Tavangar and Shooshpasha, 2016). Therefore, the present study was conducted to understand the effect of footing size on optimum geometrical parameters of jute geotextile reinforcements in sand bed i.e. the placement depth of first reinforcement layer (u) and spacing between the reinforcement layers (h). A circular footing was used to perform the model tests on both unreinforced and reinforced sand beds. Each test was repeated for two times to ensure the repeatability of the test results.

2 Experimental Program

2.1 Materials

Sand

All the laboratory model tests were performed using clean and dry sand. The sand was collected from Chennai surrounding localities. The index and physical properties of sand are presented in Table 1.

Table 1. Properties of sand (after Buragadda and Thyagaraj 2019)

Property	Values
Specific gravity, G	2.68
Sand (%)	99
Fines (%)	1
D_{10} (mm)	0.25
D_{30} (mm)	0.42
D_{60} (mm)	0.95
C_u	3.8
C_c	0.743
e_{max}	0.666
e_{min}	0.466
Soil classification	SP

Geotextiles

The present laboratory model tests were performed on reinforced sand beds using natural woven jute geotextile (JGT). The natural woven jute geotextile was procured from the National Jute Board (NJB) approved company – Ballyfabs International Ltd., Chennai, India. Table 2 presents the physical and mechanical properties of the jute geotextile.

Table 2. Properties of jute geotextile (after Buragadda and Thyagaraj 2019)

Properties	Value
Physical properties	
Thickness (mm)	1
Mass per unit area (g/m^2)	315
Mechanical property	
Ultimate tensile strength (kN/m)	
Machine direction (MD)	13.8
Cross-machine direction (CMD)	12.5
Failure strain (%)	
Machine direction (MD)	4.9
Cross-machine direction (CMD)	5.9
Axial stiffness, EA (kN/m)	246

2.2 Laboratory test set-up

A steel tank having inner dimensions of 450 mm × 450 mm × 350 mm was used for performing the model tests. The depth of sand bed was maintained as 300 mm. The sand beds were prepared by adopting an air-pluviation technique to a relative density (R_d) of 70%. A 50 mm diameter circular footing made with 25 mm thick rigid mild steel was used for the present model tests. In order to increase the roughness of the footing base, a thin layer of sand was affixed using an araldite. A hydraulic jack which was welded to the reaction frame was used for push the footings in to the sand beds.

The laboratory model tests were performed on unreinforced sand and jute geotextile sand beds by placing the jute geotextile at various depths. To find out the effect of footing size on placement depth of first reinforcement layer from the footing base (u) and spacing between the reinforcement layers (h), the reinforcement was placed at different depths i.e. 0.2D, 0.3D and 0.4D. A 10kN precalibrated proving ring was used for the load application on the footing followed accordance to IS 1888-1982. Fig. 1 shows the schematic diagram of the reinforced sand bed. The footing settlements were determined by using dial gauges D_1 and D_2 as shown in Fig. 1.

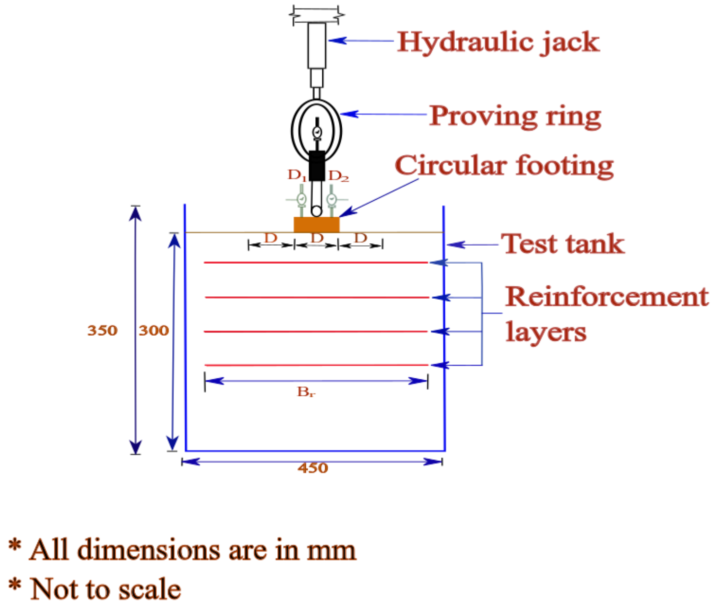

Fig. 1. Geometry of the multi-layered reinforced sand bed.

3 Results and Discussion

Bearing capacity ratio (BCR) is used to evaluate the improvement of soil load-carrying capacity with reinforcement layers. The BCR is defined as per Binquet and Lee (1975a, b) as:

$$\text{BCR} = \frac{\text{Reinforced soil bearing capacity } (q_{rs})}{\text{Unreinforced soil bearing capacity } (q_{us})} \quad (1)$$

where the bearing capacity of reinforced sand (q_{rs}) and unreinforced sand (q_{us}) are at the same settlement(s), respectively. However, at higher settlements the ultimate bearing capacity of the unreinforced soil (q_{ult}) is used in place of q_{us}.

Figs. 2 and 3 show the variation of pressure-settlement behavior of both unreinforced and reinforced sand beds for different depths of topmost reinforcement layer from the footing base (u) and different vertical spacing between the reinforcement layers (h) using single and four numbers of reinforcements, respectively. It can be observed from Fig. 2 that the load-settlement behavior of reinforced sand bed shows a pronounced peak for u = 0.3D and 0.4D. Similarly, Fig. 3 also shows the pronounced peak for vertical spacing of the reinforcement layers, h = 0.3D. This is due to the rupture of jute geotextile as shown in Fig. 4.

Figs. 5 and 6 show the variation of bearing capacity ratio (BCR) with different ratios of u/D and h/D, respectively. For comparison, the results of BCR for 150 mm diameter (D) footing derived from Buragadda and Thyagaraj (2019) are also presented in Figs. 5 and 6. Figs. 5 and 6 show the variation of BCR for only footing settlement (s/D) of 12%. According to Tafreshi and Dawson (2010), the footings should not be allowed to settle more than 15% of footing diameter (D). Hence, the variation of BCR is shown only for footing settlement (s/D) of 12%, irrespective of size of the footing (D).

Table 3 presents the optimum placement depth of first reinforcement layer (u/D) and optimum vertical spacing between the reinforcement layers (h/D) for footing sizes (D) of 50 mm and 150 mm. Table 3 shows the values of optimum u/D for two different sizes of the footings as same i.e. 0.312D (D = 50 mm) and 0.31D (D = 150 mm). However, the values of optimum h/D for two different size footings vary, even though the variation is not much significant i.e. 0.29D (for D = 50 mm) and 0.3D (for D = 150 mm). The variation factor for two different diameter footings (50 mm and 150 mm) is almost 3. Also, the type of the reinforcement used was same in all the model tests. Finally, the variation is relatively higher for optimum vertical spacing of the reinforcement (h) than the optimum placement depth of first reinforcement layer from the footing base (u).

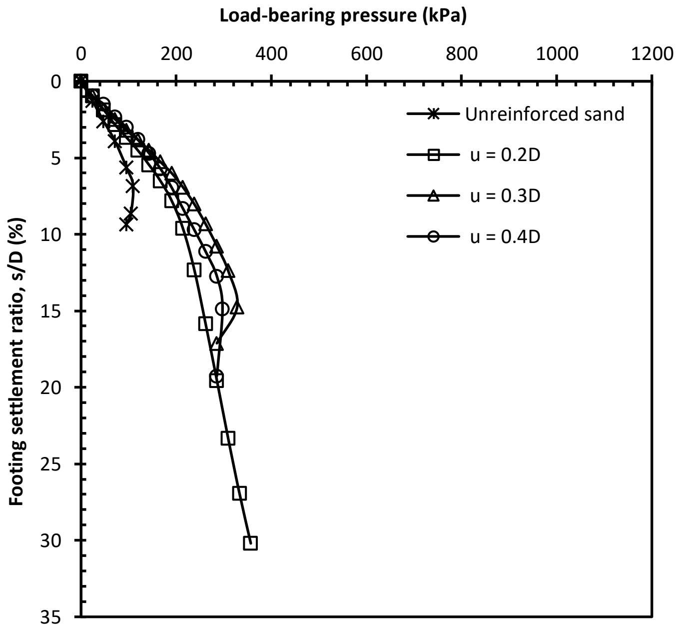

Fig. 2. Comparison of load-settlement curves of unreinforced and geotextile reinforced sand beds at different placement depths of the reinforcement layer (u/D).

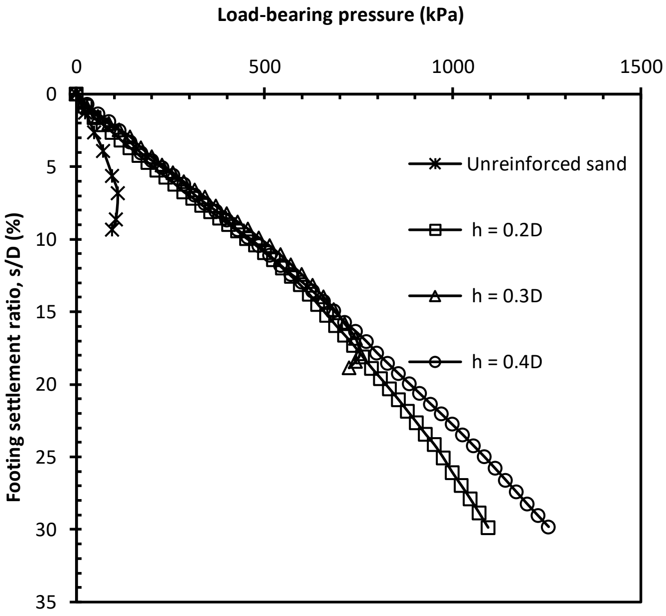

Fig. 3. Comparison of load-settlement curves of unreinforced and geotextile reinforced sand beds at different vertical spacing of reinforcement layer (h/D).

Fig. 4. Image of ruptured jute geotextile after plate load test.

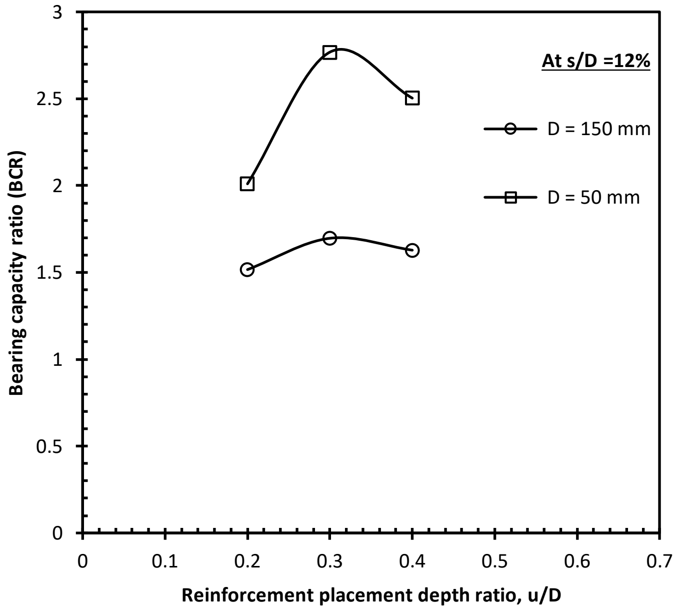

Fig. 5. Variation of the BCR with different ratios of u/D using footings of different size (D).

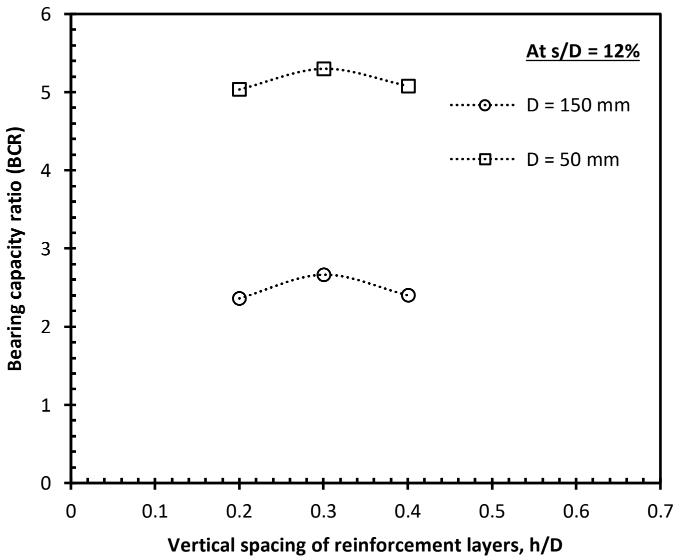

Fig. 6. Variation of the BCR with different ratios of h/D using footings of different size (D).

Table 3. Summary of test results in terms of optimum reinforcement geometrical parameters

Footing size (D)	Optimum geometrical parameter	
	u/D	h/D
50 mm	0.312	0.29
150 mm	0.31	0.3

4 Conclusions

The present experimental studies were conducted to understand the effect of footing size on the optimum geometrical parameters of the reinforcements i.e. the placement depth of first reinforcement layer (u) and spacing between the reinforcement layers (h). The test results show that the effect of footing size (D) on optimum placement depth of first reinforcement layer (u/D) and optimum vertical spacing between the reinforcement layers (h/D) is not significant even though the variation of footing size ratio is almost 3.

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