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Study of bearing capacity of strip footing resting on reinforced sand

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ABSTRACT: This research was performed to investigate the behavior of strip footing on geosynthetic reinforced sandy soil and to study the effect of different parameters contributing to their performance using laboratory model tests. The parameters investigated in the study included top layer spacing (u), width of reinforcement (b), vertical spacing between layers (s) and number of reinforcement layers (N). The test was performed on a mild steel tank having dimensions of 1.5 m × 1.5 m × 0.6 m and plate having size 30 cm × 90 cm × 2.5 cm. Test results shows that the optimum depth of reinforcement is 0.6B and the optimum width of reinforcement layer is 3B. The best spacing between geogrid layers which gives higher bearing capacity is at 0.4B and effective number of layers obtained as 3.

KEYWORDS - Geogrid reinforcement, plate load test, optimum width of layer, vertical spacing of reinforcements, number of reinforcemnt layers.

1. INTRODUCTION

Behavior of foundations on reinforced sand bed is one of the most interesting topic in geotechnical engineering. The type and the quality of reinforcements have been changed a lot. The use of polymeric reinforcements such as geotextiles, geogrids and geonets has been increasingly expanding. Up to now, many experimental and numerical studies have been made to determine the bearing capacity of shallow foundations on different soils reinforced by different elements such as metal strips, metal rods, tire shreds and geosynthetics. Recently, Ronad (2014) conducted an experimental study to investigate the bearing capacity of the square footing resting on geogrid reinforced sand bed[8].The test results showed that the beneficial use of geogrid reinforcement in terms of increasing in the bearing capacity and minimizing the settlement. Fig. 1 shows the classical scheme of a system of reinforced soil for a square foundation with B×B dimensions and N reinforcement layers. The dimensions of reinforcements are b×b and the distance between their first layer and the foundation bottom is denoted by u. The depth of the reinforcement area can be found using equation 1.

$$d = u + (N-1) \times s \qquad (1)$$

In this study effect of various factors such as top layer spacing (u), width of reinforcement (b), vertical spacing between layers (s) and number of reinforcement layers (N)are computed experimentally.

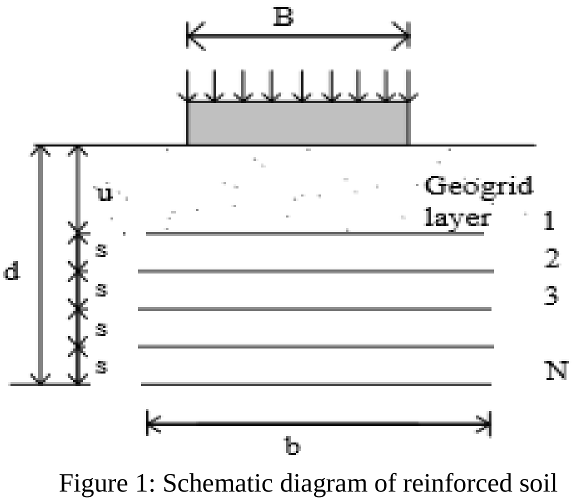

Figure 1: Schematic diagram of reinforced soil

2. LABORATORY MODEL TESTS

2.1 Test tank and model footing

In the present study the model tests were conducted in the laboratory using the tank of mild steel, having inside dimensions of 1.5 m × 1.5 m in plan and 0.60 m in depth. Tank was strengthened in horizontal and vertical directions using a channel shaped steel section to avoid lateral bulging of tank walls during filling of the sand bed and during loading conditions

A model strip footing made of mild steel, with the dimensions of 900 mm in length, 300 mm in width, and 25 mm in thickness was used in the experimental study. The two ends of the footing plate were polished smooth to minimize the end friction effect.

2.2 Test material

The sand used for this research was well graded sand. The properties of sand is determined by different soil tests as per relevant Indian Standards shown in Table 1.

Table 1: Properties of Sand

Soil property	Value
Soil type	Sand
Effective size (D_{10})	0.11 mm
Uniformity coefficient (C_u)	3.06
Coefficient of curvature (C_c)	1.11
Classification	Well graded
Cohesion, C	0 kN/m^2
Angle of internal friction, φ	36.5
Maximum dry density, γ_{max}	16.60 kN/m^3
Minimum dry density, γ_{min}	14.19 kN/m^3
Specific gravity	2.6

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

2.3 Reinforcement

A biaxial geogrid of STRARAGrid SG30X30 with a peak tensile strength of 30 kN/m was used as reinforcing material for the model tests. Typical physical and technical properties of the grids were obtained from manufacturer's data sheet and are given in Table 2.

Table 2: Properties of Geogrid

Sr. No.	Properties	Value
1	**Peak Tensile Strength**	
	Machine direction	30 kN/m
	Cross machine direction	30 kN/m
2	**Physical Properties**	
	Colour	Black
	Polymer type	HDPE
	Coating	PVC
	Aperture shape	Square
	Aperture size	25 × 25 mm

3. EXPERIMENTAL STUDY

An experimental program was carried out to study the behavior of strip footing resting on geogrid reinforced sand bed. The experimental test setup is shown in Fig. 2.Model soil samples with a height of 600 mm were constructed in layers. In order to determine the behavior of geogrid reinforced soil foundation two types of load tests were conducted, one with geogrid reinforcements, and other without reinforcement. For the tests the tank was filled with sand at 70% relative density. Initially, the behavior of the footing on unreinforced sand was determined. The tests were conducted with the inclusion of geogrid at predetermined depths. One to four geogrid layers were placed at different depths in the tank. The footing was placed in position and the load was applied. The load was applied in small increments until reaching failure. The load and corresponding foundation settlement were measured. Tests were performed to study the effect of different u/B, b/B, s/B ratios for different layers of reinforcement on load settlement characteristics.

Figure 2: Experimental setup

4. RESULTS AND DISCUSSIONS

Tests were conducted on soil without reinforcement. The ultimate bearing capacities q_u, obtained from the test are ploted in Fig.3. From experimental study ultimate bearing capacity obtained as 17.03 kPa.

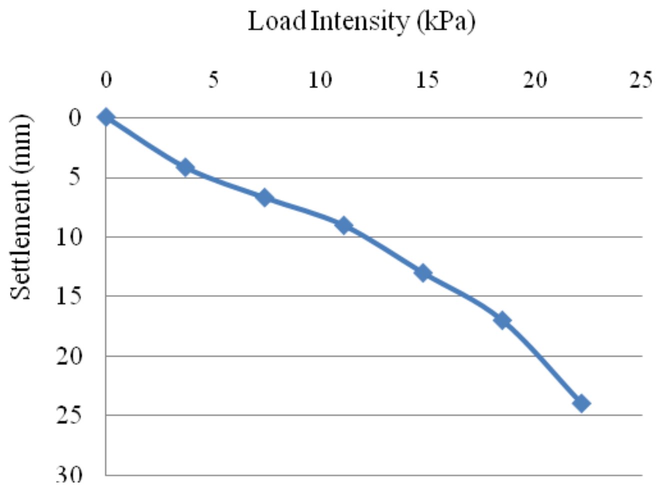

Figure 3: Load intensity – Settlement curve of unreinforced sand

5. OPTIMUM DEPTH OF FIRST LAYER REINFOECEMENT

Test was conducted with a layer of reinforcement. Analysis were performed for u/B values of 0.2, 0.4, 0.6 and 0.8. The ultimate bearing capacities q_u, for different u/B ratios are ploted in Fig. 4. As can be seen, depth of reinforcement layer has a significant impact on the improvement of the bearing capacity. Initially, with the increase in u/B up to 0.6, B.C increases and then decreases. Hence the optimum depth of reinforcement is taken as 0.6 times the width of footing.

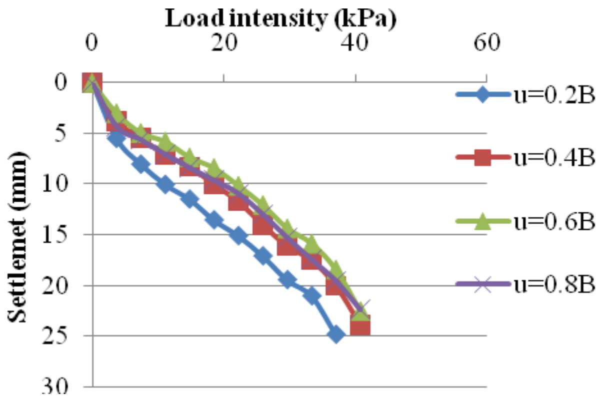

Figure 4: Load intensity – Settlement curve for different value of u/B

6. OPTIMUM WIDTH OF REINFOECEMENT

Test was conducted with a layer of reinforcement which is located at depth of 0.6B. Effect of b/B were evaluated by taking b/B values equal to 1, 2, 3 and 4. The ultimate bearing capacities q_u for for different b/B ratios are ploted in Fig. 5. It is seen that with the increase in b/B, load intensity reaches its maximum value when b/B equal to 3 and then decreased. Hence the optimum width of reinforcement is observed as 3 times the width of footing.

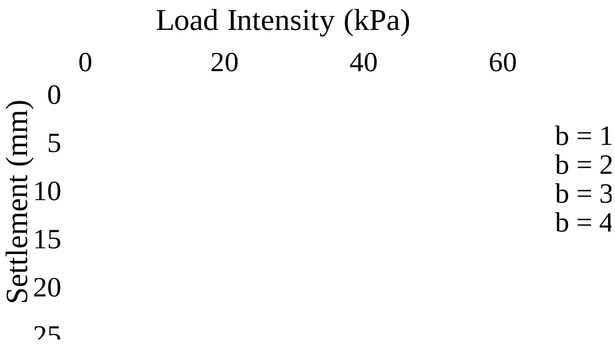

Figure 5: Load intensity – Settlement curve for different value of b/B

7. OPTIMUM SPACING BETWEEN LAYERS

Bearing capacity of the footings changes with the change in the vertical spacing between reinforcement layers. The test was conducted with two layers of reinforcement in which first layer is fixed at depth of 0.6B and second layer placed at different spacing such as 0.2B, 0.4B and 0.6B.The ultimate bearing capacities q_u for for different b/B ratios are ploted in Fig. 6. From the graph, it is clear that with the increase in s/B, load intensity reaches its maximum value when s/B equal to 0.4 and then decreased. Hence the best vertical spacing between layers is obtained as 0.4 times the width of footing.

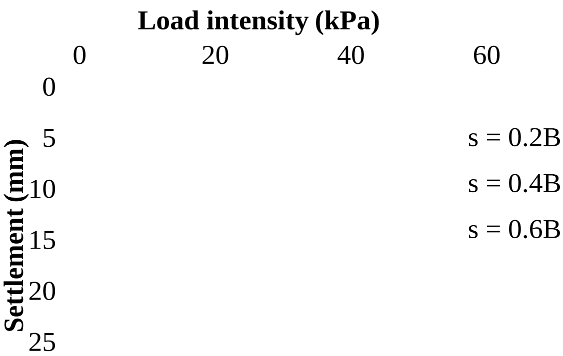

Figure 6: Load intensity – Settlement curve for different value of s/B

8. OPTIMUM NUMBER OF LAYERS

Test was conducted with different layers of reinforcement such as 1, 2, 3, and 4. Top layer geogrid is placed at 0.6B depth and successive layers are placed with vertical spacing of 0.4B. Width of each layer reinforcement is 3 times the width of footing. The optimum number of reinforcemnt layer is obtained as 3, which shows maximum bearing capacity with reduced settlement (Fig. 7).

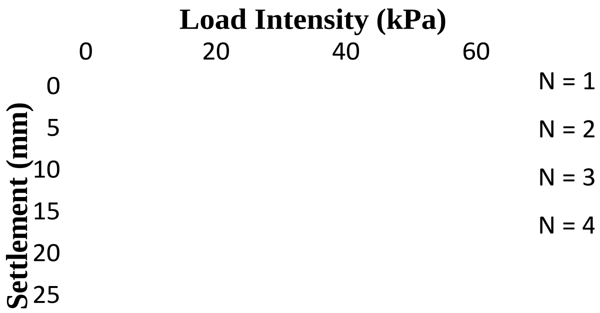

Figure 7: Load intensity – Settlement curve for different N

9. CONCLUSIONS

An experimental study of strip footing supported on geogrid reinforced sand is presented. From the study it was found that the geogrid can be effectively used for bearing capacity improvement for cohesion less soils such as sand. The various findings from the study are listed below.

- Provision of the geogrid reinforcement layers improves the load carrying capacity of the model footing.
- With the increase in u/B, B.C increases initially upto the ratio 0.6 and then decreases. Hence, 0.6B is the optimum depth of reinforcement.
- With the increase in b/B, B.C is increased initially upto 3. After that, with further increase in b/B, reduction in the BCR is occurred. So, 3B is the optimum width of reinforcement.
- The best spacing between layers of reinforcement is 0.4 times the width of footing.
- Number of reinforcement layers which have high bearing capacity is obtained as 3.

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