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STUDY OF STRIP FOOTING RESTING ON GEOGRID REINFORCED SAND

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ABSTRACT: This paper presents the effect of the depth of reinforcement from the base of footing (u) and the effect of the width of reinforcement (b) on load settlement characteristics of strip footing. The behavior of model strip footing on geogrid reinforced sand was analyzed by numerical and laboratory model test. The variation in BCR at different u/B and b/B ratios were determined. Test results shows that the optimum depth of reinforcement is 0.6B and the optimum width of reinforcement layer is 3B. Failure load obtained from physical model study was compared with that determined from FEA using PLAXIS 2D.

INTRODUCTION

A footing is the supporting base of a structure, which transmits the loads to the natural ground. Bearing capacity problems are getting wider day by day with the advent of the researchers to improve the foundation soil condition by including new material into the soil in various forms. For the last three decades, several studies have been conducted related to the beneficial effect of the geosynthetic materials, on the load bearing capacity of soils in the road pavements, shallow foundations, and slope stabilization. Several studies have been conducted on the improvement of load bearing capacity of shallow foundations supported by sand reinforced with various reinforcing materials such as geogrids, geotextile, fiber, metalstrips, and geocell. 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, at an optimum depth and width of reinforcement.

This paper presents the effect of ratio of the depth of first layer reinforcement from the base of footing (u) to the width of footing (B) and the effect of ratio of the width of reinforcement (b) to the width of footing on load settlement characteristics of strip footing. The behavior of model strip footing on geogrid reinforced dense sand was analyzed by numerical and laboratory model test. The failure load obtained from the physical model study was compared with that determined from finite element analysis using PLAXIS 2D.

LABORATORY MODEL TESTS

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.

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	26.5
Maximum dry density, γ_{max}	16.60 kN/m^3
Minimum dry density, γ_{min}	14.19 kN/m^3
Specific gravity	2.6

Geogrid 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.

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Table 2: Properties of Geogrid (StrataGrid™ BX)

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

Experimental Setup and Test Program

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. 1. 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 un-reinforced 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 and b/B ratios on load settlement characteristics. The geometry of the soil, model footing, and soil reinforcement is shown in Fig. 2.

Fig. 1 Experimental setup

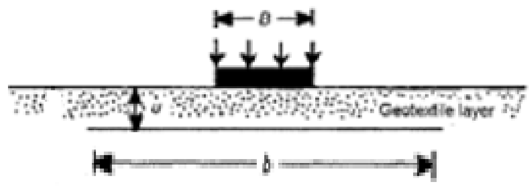

Fig. 2 Geometric parameters studied in the test

NUMERICAL STUDY

Two-dimensional plane strain FE numerical simulations were performed using Plaxis commercial program. PLAXIS can address a wide range of geotechnical problems, such as deep excavations, tunnels, and earth structures (for example, retaining walls and slopes). It was assumed that foundation is rigid. Hence, a uniform settlement applied in the vertical direction to all nodes at the soil-footing interface. The model mesh was generated using 15-node triangular elements. Typically adopted mesh is shown in Fig. 3.

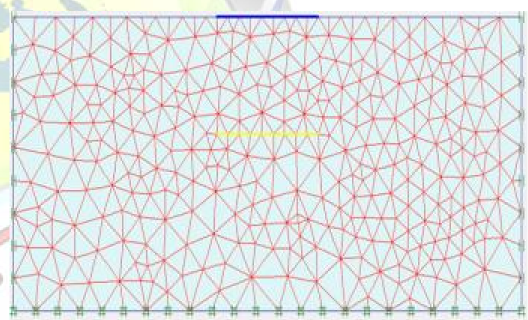

Fig. 3 Prototype footing, geometry, generated mesh, and boudary conditions (FEA)

An elastic-plastic Mohr Coulomb (MC) model was selected for the soil beneath the foundation. Material properties that have been adopted in this study are presented in Table 1 and Table 2. Experimental results were verified through numerical modeling by using FEM. Plane strain elastoplastic finite element analysis (FEA) was conducted by using the commercial program PLAXIS 2D. The initial conditions generally comprise the initial groundwater conditions, the initial geometry configuration, and the initial effective stress state. The sand layer was dry, which made implementing ground water condition unnecessary. However, the analysis required the generation of initial effective stresses via K0 procedure. The geometry of the prototype footing system was similar as that of the laboratory model.

RESULTS AND DISCUSSIONS

Bearing Capacity Without Soil Reinforcement

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Tests were conducted without reinforcement. The ultimate bearing capacities q_u, obtained from the test are ploted in Figure 4 and 5. From FEA ultimate bearing capacity obtained as 17.22 kPa and from experimental study ultimate bearing capacity obtained as 17.03 kPa.

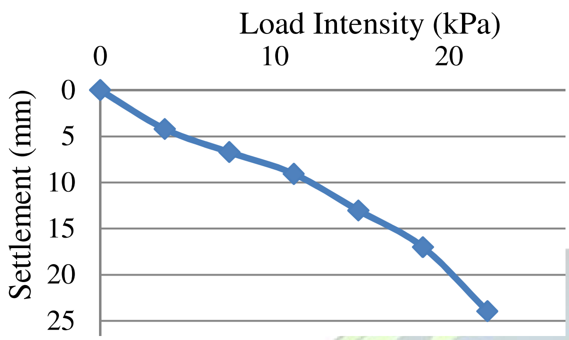

Fig. 4 Load intensity – Settlement curve of unreinforced sand from experimental study

Fig. 5 Load intensity – settlement curve of unreinforced sand from FEA

Effect of depth of first layer of reinforcement

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 Figure 6 and 7.

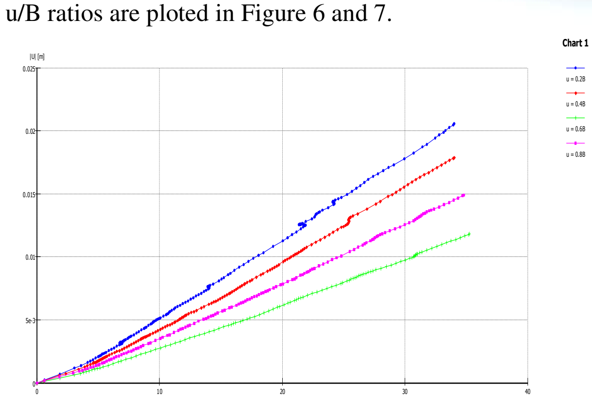

Fig. 6 Load FEA

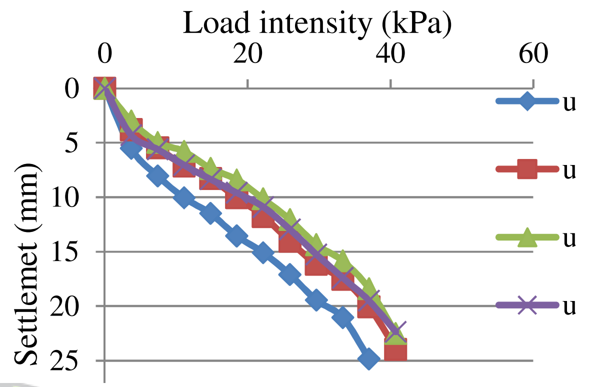

Fig. 7 Load intensity – Settlement curve for different value of u/B from experimental study

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.

Effect of width of reinforcement

Test was conducted with a layer of reinforcement which is located at u/B ratio 0.6. 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 Figure 8 and 9.

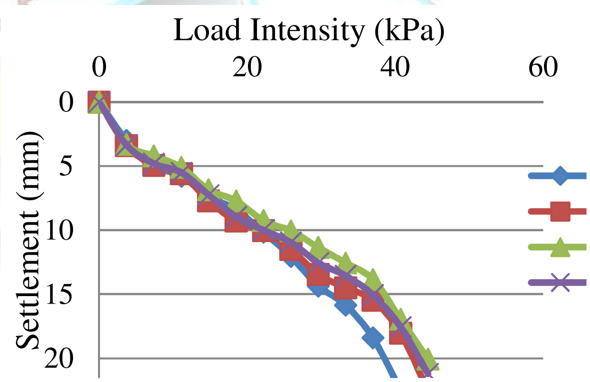

Fig. 8 Load intensity – Settlement curve for different value of b/B from experimental study

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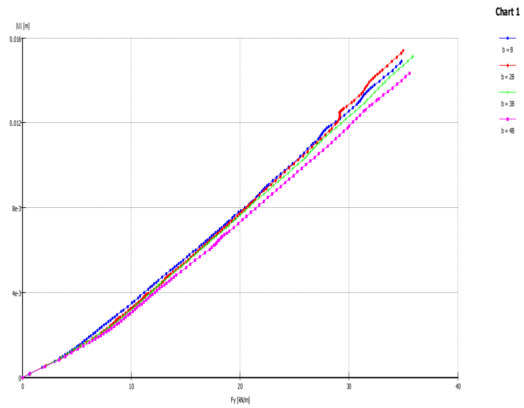

Fig. 9 Load intensity – Settlement curve for different value of b/B from FEA

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.

Strength Improvement Ratio

In order to get a quantitative assessment of the extent of soil improvement, the improvement due to the provision of geogrid reinforcement can be shown in nondimensional strength improvement ratio which is define as "the ratio of the ultimate bearing capacity of the reinforced sand to the un-reinforced sand" which is same as bearing capacity ratio (BCR). BCR for different u/B ratios are plotted in Figure 10 and BCR for different b/B ratios are plotted in Figure 11.

$$BCR = \frac{\text{Ultimate bearing capacity of reinforced sand}}{\text{Ultimate bearing capacity of un-reinforced sand}} \quad (1)$$

Strength improvement ratio increases up to a depth ratio u/B = 0.6, thereafter it decreases with further increases in depth ratio. This is due to the fact that the magnitude of the mobilized frictional resistance at the interface of sand and the reinforcement. The BCR increased with increasing geogrid layer width. This improvement in the ultimate bearing capacity with an increasing layer width has been significant until an amount of b/B = 3. Further increase in layer width of geogrid did not show important contributions in increasing the ultimate load of the footing.

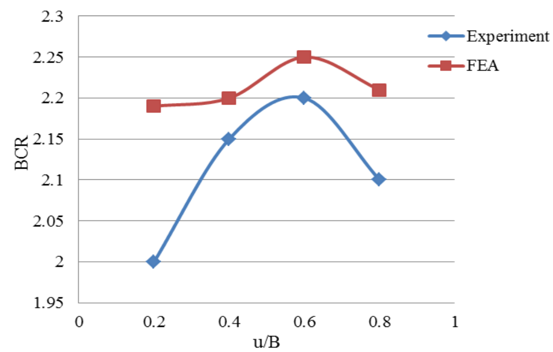

Fig. 10 Variarion of BCR with different u/B ratio

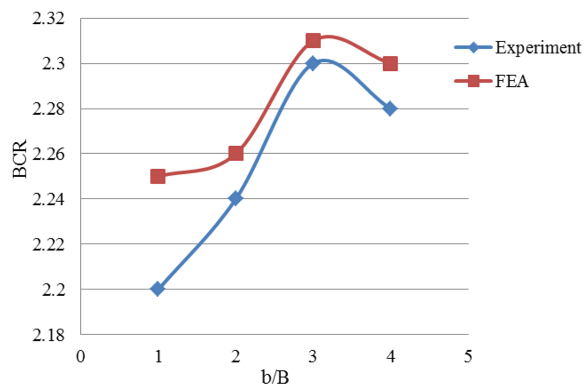

Fig. 11 Variation of BCR with different b/B ratio

Similar studies were conducted by Ahmadi and Asakereh [1], to investigate the behavior of strip footing on reinforced soil. The results showed that with the increase in u/B up to 0.5, BCR increases and then decreases. In the case of width of reinforcement BCR is increased with increase b/B up to a value equal to 1 and then decreased.

CONCLUSIONS

An experimental and numerical study of strip footing supported on geogrid reinforced sand is presented. Based on the test results, following main conclusions are made:

- Provision of the geogrid reinforcement layers improves the load carrying capacity of the model footing.
- With the increase in u/B, BCR 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, BCR is increased initially upto 3. After that, with further increase in b/B, reduction in the BCR is occurred. Hence, 3B is the optimum width of reinforcement.

- PLAXIS software overestimates the performance of physical model

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