AN EXPERIMENTAL STUDY OF SQUARE FOOTING RESTING ON GEO-GRID REINFORCED SAND

Hemantkumar Ronad[1]

[1]*M.Tech in Geotechnical Engg, Department of Civil Engineering, Basaveshwar Engineering College, Bagalkot*

Abstract
A series of laboratory model test has been carried out to investigate the bearing capacity of the square footing resting on reinforced sand bed. The geo-grid as a reinforcement material has been used. In the present study an attempt has been made to study the bearing capacity of square footing on sand reinforced bed. The effect of different parameter like the depth of the upper most layer of reinforcement from the base of the model footing (u), for different densities of the sand (γ = 1.55, 1.65, and 1.75 gm/cc) the test has been carried out. Three numbers of layers, has been fixed. The test results showed that the beneficial use of geo-grid reinforcement in terms of increasing in the bearing capacity and minimizing the settlement, at an optimum depth of reinforcement, however for the higher density of the soil gives maximum bearing capacity. Therefore, for effective utilization of geo-grid reinforcement, the optimum depth should be (u= 0.33B) which is found to be good agreement with the past researchers, and the foundation soil should be in higher density.

Keywords-Sand, direct shear test, reinforced & unreinforced, geo-grid, bearing capacity.

--***--

1. BACKGROUND

During the past three decades, results of several studies have been published that relate to the evaluation of the ultimate and allowable bearing capacities of shallow foundations supported by sand reinforced with multi-layered geo-grid. The concept of reinforced soil is based on the existence of tensile strength of reinforcement and soil reinforcement interaction due to frictional, interlocking and adhesion properties. The method of reinforcing soil with layers of individual reinforcements placed horizontally as described here is best attempted in conjunction with fills that are required to support shallow foundations such as footings. The beneficial use of reinforcement materials like metal strips and geosynthetics to increase the bearing capacity of sand has been clearly established.

2. BEARING CAPACITY THEORY

2.1 Terzaghi's Analysis

An analysis of the condition of complete bearing capacity failure, usually termed general shear failure, can be made by assuming the soil behaves like an ideally plastic material. This concept was first developed by Prandtl and later extended by Terzaghi. He considered a footing of width B and subjected to a loading intensity q_f to cause failure. The footing is shallow is equal to or less than width B of the footing. The loading soil fails along the composite surface $fede_1f_1$. This region is divided into three zones zone 1, two pairs of zone 2 and two pairs of zone 3. When the base of the footing sinks into the ground, zone 1 is prevented from undergoing any lateral yield by the fraction and adhesion between the soil and the base of the footing. Thus zone 1 remains in the state of elastic equilibrium and it acts as if it were a part of the footing. Its boundaries d_a and d_b are assumed as plane surfaces, rising at an angle $\varphi = \emptyset$ with the horizontal zone 2 is called the zone of radial shear these lines are straight while the lines of the other set are the logarithmic spirals with their located at the outer edges of the base of the footing. zone 3 is called the zone of linear shear, and is identical with that for rankines passive state The boundary of zone 3 rise at (45 - $\emptyset$/2) with the horizontal the failure zones are assumed not to extend above the horizontal plane through ab of the footing .this implies the shear resistance of the soil above the horizontal plane through the base of the footing is neglected, and the soil above this plane is replaced with a surcharge q=γ x D_f.
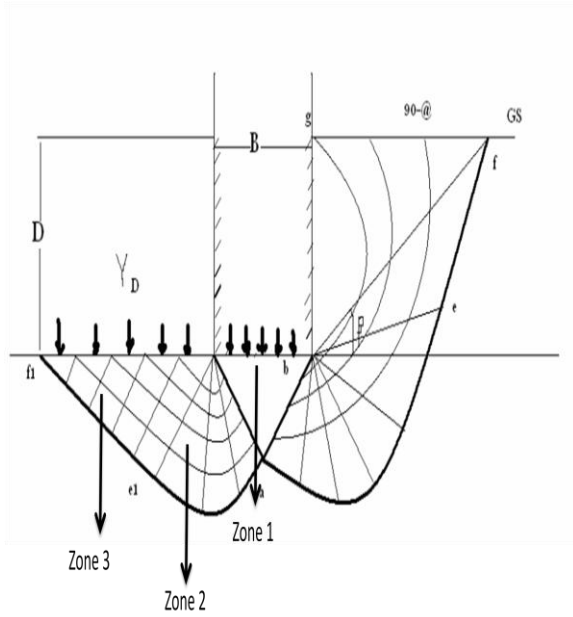
Fig 2.1 Terzaghi's theory of shallow foundation

3. Materials and Experimental Study

3.1 Sand

The medium used in the present study is Krishna river sand, Krishna mandal. The angle of internal friction ($\emptyset$) obtained from the laboratory direct shear test. The dry unit weight 1.75 gm/cc & Angle of internal friction is 37°.

3.2. Geosynthetics

Two types of geosynthetics namely geo-grid (SG-700) were used as the reinforcement material in the sand bed for the model tests.

Table 3.1 Physical properties of Geo-Grid.

TYPE	SG 700
Tensile strength (KN/m^2) MD	170
Long term design strength (KN/m^2) in Sand	93.15
Grid Size, Machine Design (mm)	60 x 25

3.3 Model Footing

The model square footing used was a hard wooden piece of 150 mm x 150 mm size and 25 mm thickness. The base (bottom) of the model footing was made rough by cementing a thin layer of sand to it using epoxy glue.
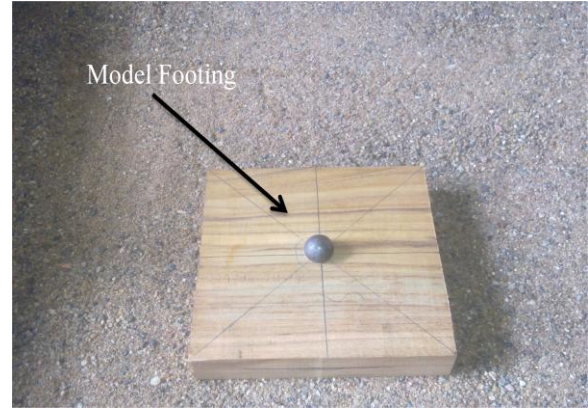

Fig. 3.1 Photographic view of the model footing

4. EXPERIMENTAL STUDY

In the present study the model tests were conducted in the laboratory using the wooden box tank which was designed keeping in mind the size of model footing to be tested and the zone of influence. The inside length, width and height of the wooden tank are 600 mm, 600 mm and 600 mm respectively. The tank was strengthened in horizontal directions using a channel shaped steel section to avoid lateral deformation/bulging of tank walls during filling of the sand bed and during loading conditions. The footing was loaded by a hand operated screw jack supported against a reaction frame. The layout and configuration of the setup is shown in Fig 4.1
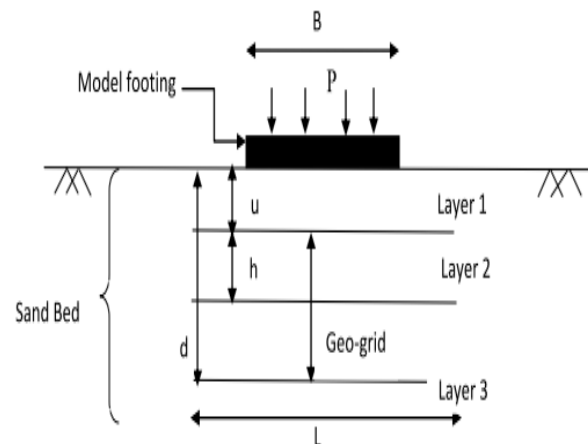

Fig. 4.1 Layout and configuration of planar reinforcement layers in the model tests

5. RESULT & DISCUSSION

In the present study includes observations and discussions of the experiments carried out to examine (i) optimum depth of reinforced zone (ii) density of the soil, checking improvement of bearing capacity (iii) strength improvement ratio (iv) settlement reduction factor.

5.1 Un-Reinforced Sand Test for the Square Footing

The tests results for the unreinforced foundation bed were plotted; the load-deformation curve for the density 1.75 gm/cc, 1.65 gm/cc and 1.55 gm/cc are plotted and shown in the Fig. 5.1.
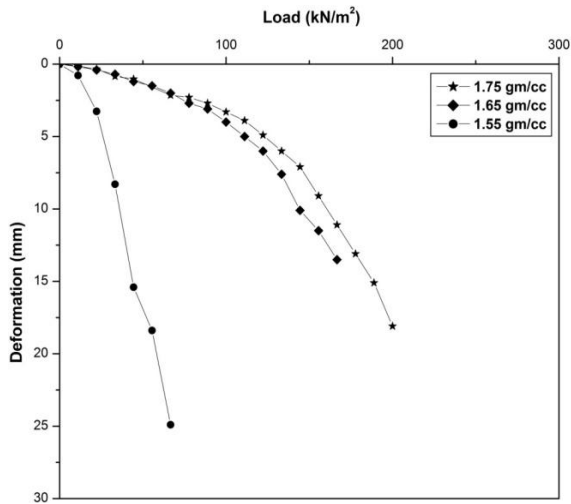

Fig 5.1 Variation of the load with deformation for unreinforced foundation bed

Table 5.1 Ultimate bearing capacity for different density and u/B ratio

	Ultimate bearing capacity (kN/m^2)		
Density	**1.55 gm/cc**	**1.65 gm/cc**	**1.75 gm/cc**
Without reinforcement	30	100	106.6
Type of reinforcement	SG 700		
u/B = 0.16	147.7	160.6	174.4
u/B = 0.33	170.0	192.2	225.5
u/B = 0.66	105.5	127.3	140.0

5.2 Effect of U/B on Ultimate Bearing Capacity of the Square Footing on Reinforced Sand Bed of (SG 700).

It can be seen that, the load v/s footing deformation response of reinforced sand bed is far better than the non-reinforced case. This is due to the frictional resistance at the interface of the sand and reinforcement which would have prevented the soil mass from shearing under vertical applied load
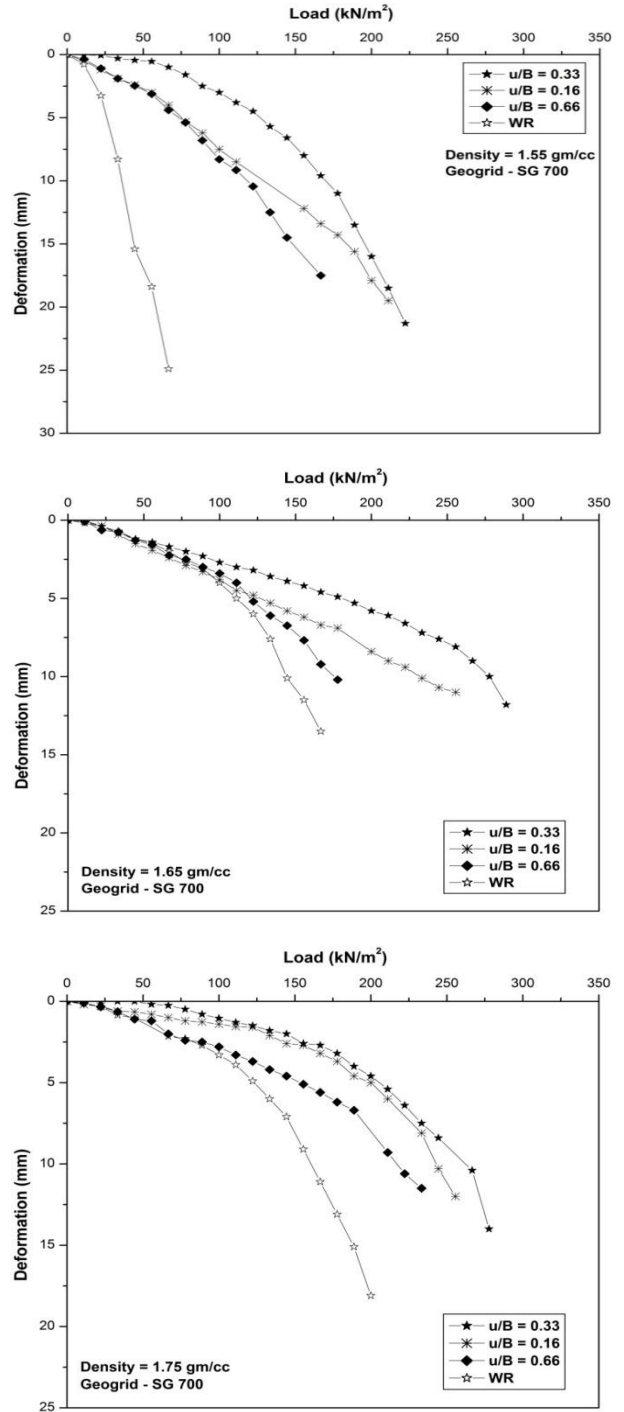

Fig.5.1 For the density 1.55 gm/cc, 1.65 gm/cc, 1.75 gm/cc load-deformation curve for u/B = 0.16, 0.33 and 0.66, and un-reinforcement for the geo-grid SG 700.

5.3 Strength Improvement Ratio

In order to get a quantitative assessment of the extent of soil improvement, the improvement due to the provision of geo-grid reinforcement can be shown in non–dimensional 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.

- Calculation of the strength improvement ratio for γ = 1.55 gm/cc, u/B = 0.33 for SG 700

Strength improvement ratio

$$= \frac{\text{Ultimate bearing capacity of reinforced sand}}{\text{Ultimate bearing capacity of un} - \text{reinforced sand}}$$

$$Strength\ improvement\ ratio = \frac{170}{30} = 5.6$$

Table 5.2 Strength improvement ratio for different density and u/B ratio.

	Strength Improvement Ratio		
Type of reinforcement	SG 700		
Density	1.55 gm/cc	1.65 gm/cc	1.75 gm/cc
u/B = 0.16	4.9	1.6	1.6
u/B = 0.33	5.6	2.0	2.1
u/B = 0.66	3.4	1.2	1.3

5.4 Settlement Reduction Factor

The improvement due to the inclusion of a geo-grid reinforcement layer in sand, in terms of reduction in footing settlement, can be known through the parameter settlement reduction factor which is defined as:

$$Settlement\ reduction\ factor = S_o - S_r / S_o$$

Where in, S_o is the settlement of the non-reinforced sand bed at a given pressure.
S_r is the settlement of the sand bed strengthened by geo-grid reinforcement at the same pressure.

- Calculation of settlement reduction factor for γ = 1.55 gm/cc, u/B = 0.33 for the geo-grid SG 700.
-

$$Settlement\ reduction\ factor = \frac{5 - 0.2}{5} = 0.96$$

Table 5.3 Settlement reduction factor for different density and u/B ratio

	Settlement Reduction Factor		
Density	1.55 gm/cc	1.65 gm/cc	1.75 gm/cc
Without reinforcement	5	3	2.3
Type of	SG 700		

reinforcement			
u/B = 0.16	0.68	0.32	0.26
u/B = 0.33	0.96	0.41	0.47
u/B = 0.66	0.60	0.28	0.30

Due to the inclusion of geo-grid at a depth of 0.33B the bearing capacity increased significantly which is quantified by strength improvement ratio and reduces settlement.

6. CONCLUDING REMARKS

- Provision of the geo-grid reinforcement layers improves the load carrying capacity of the model footing.
- Effective depth of the zone reinforcement below a square footing is twice the width of the footing (2B).
- In the case of the geo-grid reinforced both ultimate bearing capacity and bearing capacity at any settlement of square footing are maximum at u/B = 0.33.
- From the overall performance point of the view of the model footing (i.e., both strength and settlement aspects), the optimum location of the geo-grid reinforcement is about 0.33B below the base of the footing, within the effective reinforcement zone.
- Strength improvement ratio also increases up to a depth ratio u/B = 0.33, thereafter it decreases with further increases in depth ratio. This is due to the fact the magnitude of the mobilized frictional resistance at the interface of sand and the reinforcement because of the smaller or the lower overburden pressure over the reinforcement.
- Use of the geo-grid reinforcement leads to better performance from the point of view of strength improvement as well as settlement reduction.
- The experimental study results suggest the possibility of developing a predictive model for strength improvement due to use of geo-grid reinforcement.
- As the density of the soil increase the load carrying capacity increases. In order to get the effective utilization of geo-grid reinforcement, the soil should have higher density therefore the stiffness between the soil and geo-grid reinforcement increases.
- The test results showed that there is no much variation when compared with the previous investigators, the variation is within 5 to 10%.

REFERENCES

[1] Adams, M.T., Collin, J.C., 1997. Large model spread footing load tests on geogrid-reinforced soil foundations. *Journal of Geotechnical and Geoenvironmental Engineering, ASCE* **123** (1), 66–72.
[2] Gosh, A., Gosh, A., Bera, A.K., 2005. Bearing capacity of square footing on pond ash reinforced with jute geotextiles. *Geotextiles and Geomembranes* **23** (2), 144–173.

[3]   Huang, C.C., Menq, F.Y., 1997. Deep footing and wide-slab effects on reinforced sandy ground. *Journal ofGeotechnic al and Geoenvironmental Engineering, ASCE* **123** (1), 30–36.

[4]   Hataf, N., Razavi, M.R., 2000. Use of tire shreds for bearing capacity of shallow foundation on sand. In: *Proceedings of **3rd** International Conference on Ground Improvement Techniques, Singapore,* pp. 189–194.

[5]   Khing, K.H., Das, B.M., Cook, E.E., Yen, S.C., 1993. The bearing capacity of a strip footing on geogrid reinforced sand. *Geotextiles and Geomembranes* **12,** 351–361.

[6]   Madhavi Latha, G., and Somwanshi, A.B., 2009(a). Bearing capacity of square footings on geosynthetic reinforced sand. *Geotextiles and Geomembranes* **27,** 281–294.

[7]   Patra, C.R., Das, B.M., Atalar, C., 2005. Bearing capacity of embedded strip foundation on geogrid-reinforced sand. *Geotextiles and Geomembranes* **23,** 454–462.

[8]   Madhavi Latha, G., and Somwanshi, A.B., 2009(b). Effect of reinforcement form on the bearing capacity of square footing on sand. *Geotextiles and Geomembranes* **27,** 409-422.

[9]   Yetimoglu, T., Wu, J.T.H., Saglamer, A., 1994. Bearing capacity of rectangular footing on geogrid reinforced sand. *Journal of Geotechnical Engineering ASCE* **120,** 2083–2099.

[10]   Shin, E.C. and Das, B.M., 2000. Experimental Study of Bearing Capacity of a Strip Foundation on Geogrid-Reinforced Sand, *Geosynthetics International,* **Vol. 7,** No. 1, pp. 59-71.