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BEHAVIOUR OF PRESTRESSED GEOTEXTILE-REINFORCED FINE SAND BED SUPPORTING AN EMBEDDED SQUARE FOOTING

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ABSTRACT: This paper presents the results of laboratory model tests carried out on embedded square footing supported on geotextile reinforced sand bed. The effect of reinforcement with geotextile were studies through a series of laboratory model tests with different size of geotextile and depth of placement below footing. The effects of prestressing the geotextile on the strength improvement and settlement reduction of a reinforced sand bed are also being investigated. The model steel tank of size 120 cm x 50 cm x 50 cm and square footing of 10 cm are used. The study also highlights the effect of size of geotextile and placement of geotextile below footing on load-settlement characteristics.

Keywords:Bearing Capacity Ratio, Settlement Reduction Ratio, Embedded Square Footing, Geotextile, Prestress

1. INTRODUCTION

Geosynthetics soil reinforcement such as geotextiles, geogrides and geocomposites have beneficial effects on bearing capacity and settlement of shallow foundations. Considerable experimental research has been reported to study the behaviour of footing resting on geosynthetic reinforced bed (Adams and Colin, [1]; Basudhar et al., [2]; Boushehrian and Hataf, [3]; Guido et al., [4]; Khing et al.,[5]; Lackner et al., [6]; Latha and Somwanshi, [7]; Lovisa et al., [8]; Sitharam and Sireesh, [9]; Shivashankar and Jayaraj, [10]; Tafreshi and Dawson, [11]; Yasrobi et al., [12])

From the studies reported in the literature it has been observed that there is a substantial increase in bearing capacity of foundation reinforced with geosynthetics and settlement of foundation also decreases. For the maximum improvement of bearing capacity, different researchers have given different view about following design parameter.(a) u= depth of first layer of reinforcement below footing base. Value of u/B varies from 0.175 to 0.5 (B= width or Dia. of footing) (b) z = vertical spacing between reinforcement layer. Value of z/B varies from 0.2 to 0.46 (c) b= width of reinforcement layer. Value of b/B varies from 2.5 to 4.0. (d) N= No. of reinforcement layers. Value of N varies from 3 to 5.

Lovisa et al. [8] conducted laboratory model tests and finite element analyses on a circular footing resting on sand reinforced with geotextile to study the effect of prestressing the reinforcement. The prestressing force applied was equal to 2% of the allowable tensile strength of the geotextile. They observed that the addition of prestress to reinforcement resulted in significant improvement in the load bearing capacity and reduction in settlement of foundation. Lackner et al. [6] conducted about 60 path controlled static load displacement tests and 80 cyclic load displacement tests to determine the load-displacement behavior of prestressed reinforced soil structures. They concluded that prestressing the reinforcement improves the load displacement behaviour of reinforced soil structures. Also rather than a circular footing, square or rectangular footings are commonly used. Hence in this investigation an attempt is made to evaluate the effects of prestressing of reinforcement in improving the bearing capacity of embedded square footings supported on geotextile reinforced granular beds.

2. EXPERIMENTAL INVESTIGATION

The experimental program reported herein, that involves small scale model test, was carried out using a test facility in the Geotechnical Laboratory of Applied Mechanics Department at SVNIT Surat, India. Details of the experimental test program, material used, test procedure and analysis of the test results of model studies on load bearing capacity and settlement behavior of embedded square footings resting on a geotextile-reinforced sand bed and prestressed geotextile-reinforced sand bed are presented below.

2.1 Materials

The material used for granular bed is fine sand and is locally available soil known as Panna sand. The grain size distribution curve of sand is shown in Fig.1 and a property of sand is given in Table 1. The reinforcement used is geotextile and its properties are given in Table 2.

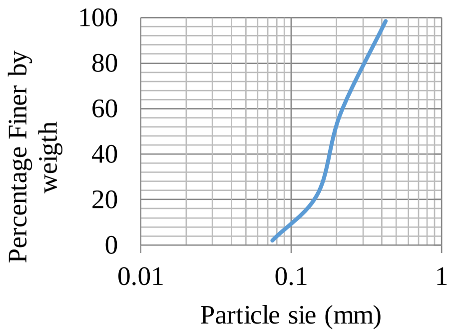

Fig.1 Grain size distribution curve for the sand

Table1 Properties of sand

Property	Value
Specific gravity	2.60
Maximum dry unit weight(kN/m^3)	17.3
Minimum dry unit weight(kN/m^3)	14.2
Dry unit weight during test(kN/m^3)	15.5
Relative density for model test(%)	46.8
Effective Grain Size,D_{10} (mm)	0.14
D_{60} (mm)	0.25
D_{30} (mm)	0.19
Coefficient of uniformity(C_u)	1.78
Coefficient of curvature(C_c)	1.03
friction angle(ϕ°)	30°
Cohesion,c(kPa)	0

Table2 Properties of geotextile

Property	Value
Mass per unit area, (g/m^2)	147
Thickness, (mm)	1.35
Tensile strength, MD(kN/m)	30
Tensile strength, CD(kN/m)	29
Tearing strength, MD(N)	612
Tearing strength, CD(N)	475
Puncture strength, (N)	637
Burst strength, (N)	290

2.2 Test setup

The model test was performed in a steel tank of dimension 1200 mm length x 500 mm width x 500 mm depth. The model footing is a mild steel plate of size 100 mm x 100 mm and 25 mm thickness. The footing was embedded at 0.5B (B=size of square footing) depth and was loaded by hand operated gear arrangement system supported against a reaction frame. The load is measured with the help of Load cell and deformation using two LVDT (Linear variable differential transformer) placed opposite to each other as shown in Fig.3. The schematic view of test apparatus is shown in Fig.2. The photograph of experimental set up is shown in Fig.3.

2.3 Preparation of test bed

The sand bed is prepared in tank using sand raining technique to achieve required density of sand in each layer. The sand bed is prepared in layers of 50 mm. The sand is filled up to bottom layer of reinforcement. The reinforcement is then placed with its centre exactly below the footing. The geotextile of different size (2Bx2B, 3Bx3B and 4Bx4B) are placed at a depth of 0.1B, 0.2B, 0.3B, 0.4B and 0.5B below footing and then prestress load (2% of the allowable tensile strength of the geotextile) is applied in both direction and is distributed over three pulleys. Then sand above the reinforcement is placed up to footing level (0.5B below surface). Then a steel box as shown in Fig. 3 is placed and then sand bed is prepared up to surface level. After placing model footing and LVDT, the left space is filled with sand before the test starts.

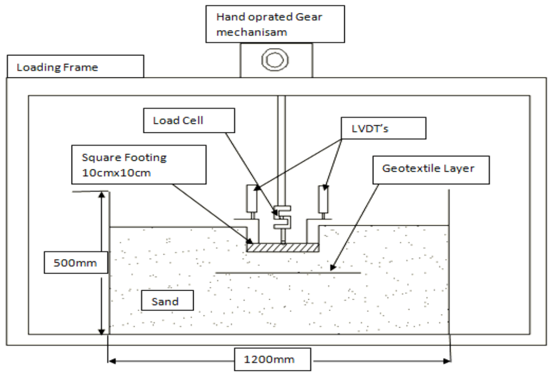

Fig.2 The schematic view of test apparatus

Fig.3 Photograph of experimental set up

2.4 Testing procedure

After the preparation of sand bed, the footing is placed exactly at the centre of geotextile and loading. The tests have been performed for unreinforced sand, reinforced sand without prestressing and reinforced sand with prestressing. Few tests have also been performed with pressure cell placed at 1B and 2B depth below footing to see the effect of geotextile below footing. The load is applied by hand operated gear arrangement system supported against a reaction frame with constant rate of penetration of 1.0 mm per min. The load is recorded with the help of load cell and settlements are recorded at two points with the help of LVDT. After the test is over, the tank is emptied and refilled for next test maintaining the same density every times. The details of testing programme are given in Table 3. In series A test was performed on unreinforced sand bed. In series B test was performed on reinforced sand bed without prestressing and in series C test was performed with prestressing in both direction. In series D, only four test was performed with pressure cell placed at two point 1B and 2B below footing with and without reinforcement.

Table 3 Details of testing programme

Series	Size of geotextile	Depth of geotextile below footing	Direction of prestress
A	-	-	-
B	2B x 2B	0.1B,0.2B,0.3B 0.4B & 0.5B	-
	3B x 3B	0.1B,0.2B,0.3B 0.4B & 0.5B	-
	4B x 4B	0.1B,0.2B,0.3B 0.4B & 0.5B	-
C	2B x 2B	0.1B,0.2B,0.3B 0.4B & 0.5B	biaxial
	3B x 3B	0.1B,0.2B,0.3B 0.4B & 0.5B	biaxial
	4B x 4B	0.1B,0.2B,0.3B 0.4B & 0.5B	biaxial
D	2B x 2B	1B & 2B	-

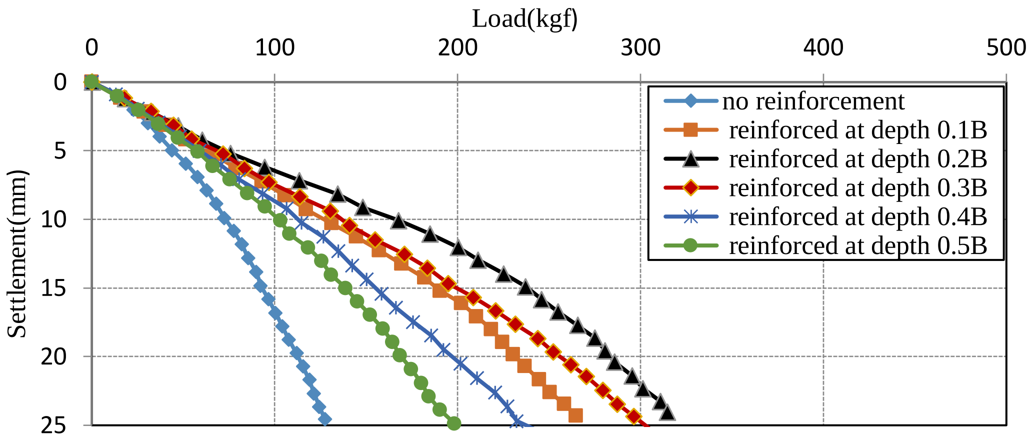

Fig.4 Load versus settlement curve for sand bed reinforced with geotextile of size 2Bx2B without prestressed

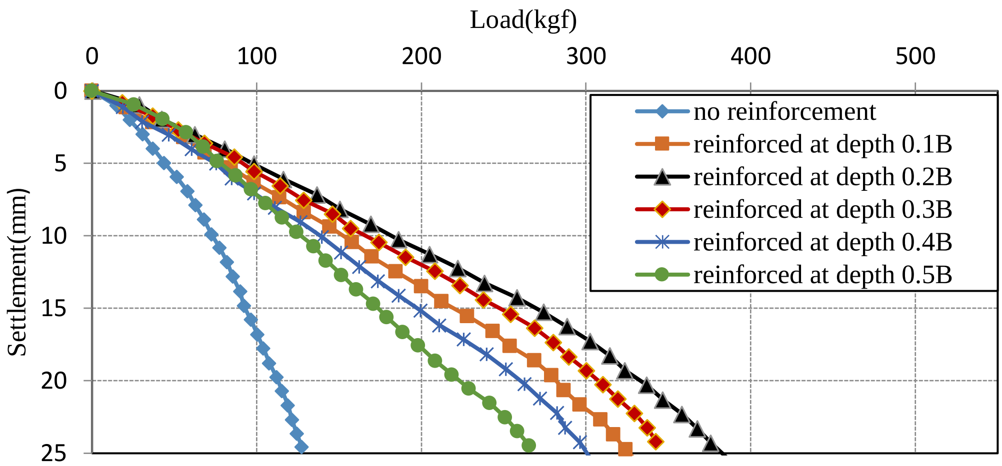

Fig.5 Load versus settlement curve for sand bed reinforced with geotextile of size 2Bx2B with prestressed

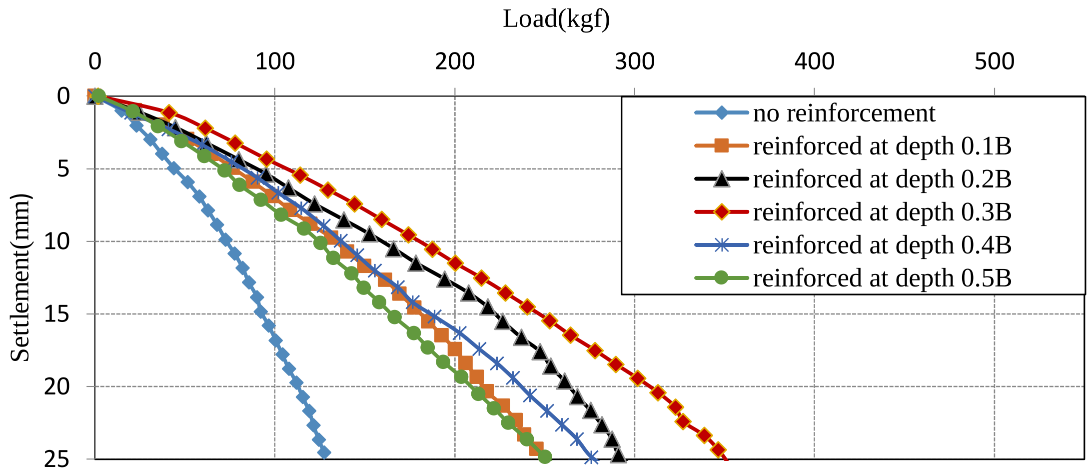

Fig.6 Load versus settlement curve for sand bed reinforced with geotextile of size 3Bx3B without prestressed

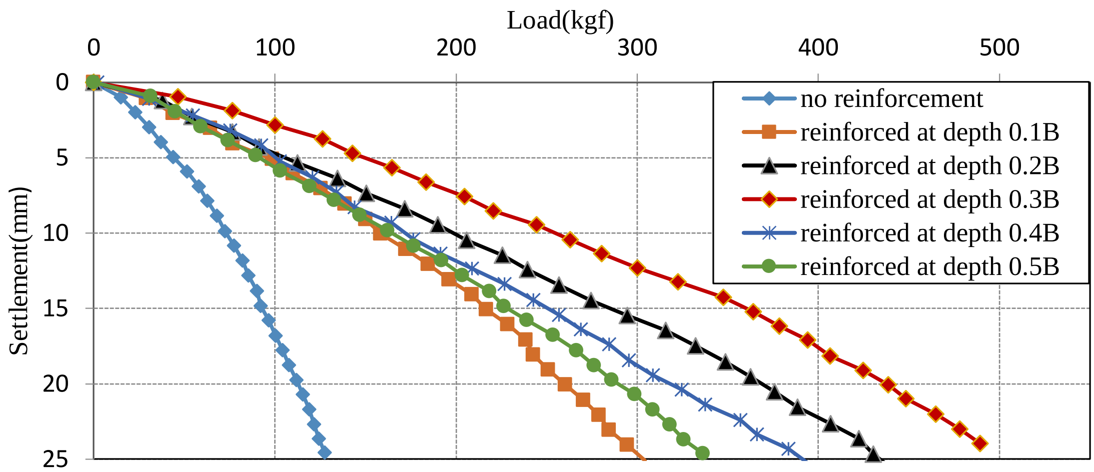

Fig.7 Load versus settlement curve for sand bed reinforced with geotextile of size 3Bx3B with prestressed

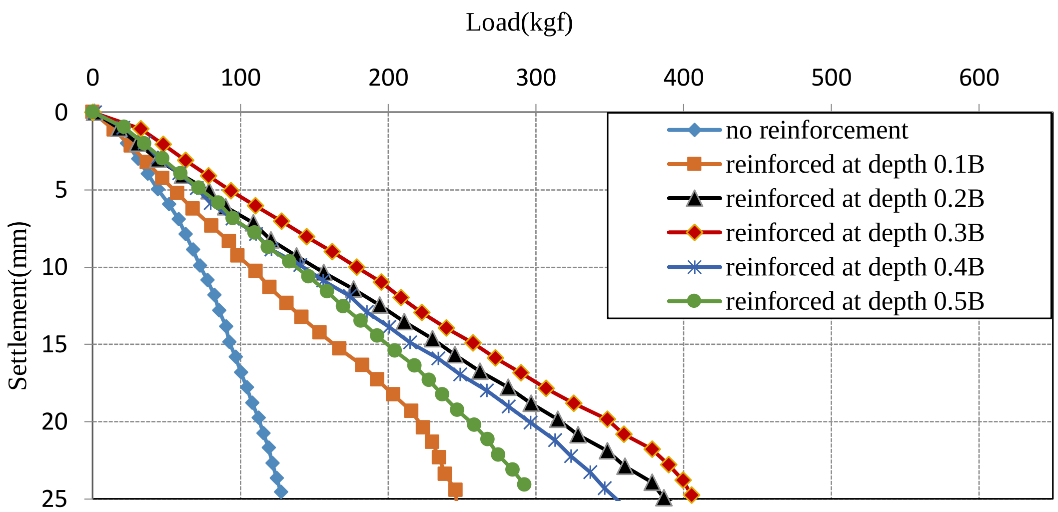

Fig.8 Load versus settlement curve for sand bed reinforced with geotextile of size 4Bx4B without prestressed

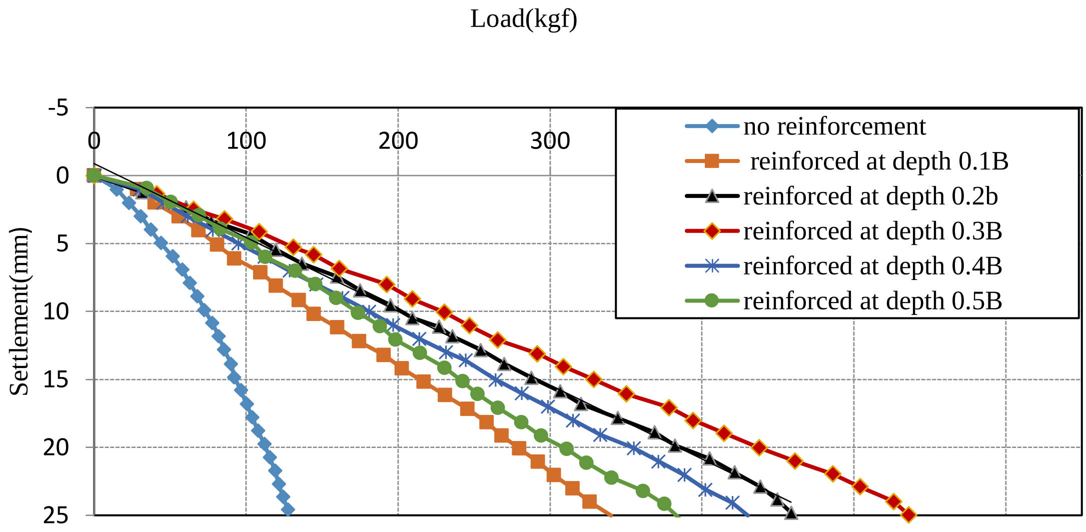

Fig.9 Load versus settlement curve for sand bed reinforced with geotextile of size 4Bx4B with prestressed

3. RESULTS AND DISCUSSIONS

Load versus settlement curve for geotextile of size 2B x 2B placed below footing at the depth of 0.1B to 0.5B ,without pretressed and with prestressed are shown in Fig.4 and Fig.5 respectively. From Fig.4 and Fig.5, it may be concluded that for geotextile of size 2B x 2B, the optimum depth of placement for maximum improvement in bearing capacity is 0.2B below footing for both the cases. Load versus settlement curve for geotextile of size 3B x 3B placed below footing at the depth of 0.1B to 0.5B ,without pretressed and with prestressed are shown in Fig.6 and Fig.7 respectively. From Fig.6 and Fig.7, it is observed that for geotextile of size 3B x 3B, the optimum depth of placement for maximum improvement in bearing capacity is 0.3B below footing for both the cases without prestressed and with pretressed. Load versus settlement curve for geotextile of size 4B x 4B placed below footing at the depth of 0.1B to 0.5B ,without pretressed and with prestressed are shown in Fig.8 and Fig.9 respectively. From Fig.8 and Fig.9, it may be concluded that for geotextile of size 4B x 4B, the optimum depth of placement for maximum improvement in bearing capacity is 0.3B below footing for both the cases.

The ratio of bearing capacity of improved soil to that of original soil is termed as bearing capacity ratio (BCR). The BCR values at 10 mm settlement are determined for various cases from load vs settlement curves and are shown in Table 4. From Table 4, it is observed that, for all size of geotextile placed at any depth below footing, there is improvement in bearing capacity when it is prestressed.

The ratio of settlement of original soil to that of improved soil for same loading is defined as settlement reduction ratio (SRR). The SRR value for load at 10mm of original soil are calculated from load versus settlement curves and are shown in Table 5. From Table 5, it may be concluded that for all size of geotextile placed at any depth below footing, there is reduction in settlement for same load, when it is prestressed.

Table 4 BCR values at 10 mm settlement

Size of geotextile	Depth of placing geotextile	BCR Without prestressed	BCR With prestressed
2Bx2B	0.1B	1.74	2.08
	0.2B	2.27	2.62
	0.3B	1.87	2.27
	0.4B	1.54	1.89
	0.5B	1.40	1.74
3Bx3B	0.1B	1.83	2.16
	0.2B	2.18	2.72
	0.3B	2.47	3.48
	0.4B	1.90	2.35
	0.5B	1.70	2.25
4Bx4B	0.1B	1.47	1.95
	0.2B	2.05	2.76
	0.3B	2.45	3.14
	0.4B	1.94	2.47
	0.5B	1.88	2.35

If we plot the load versus settlement curve of all the three size of geotextile (2Bx2B, 3Bx3B and 4Bx4B) placed at same depth below footing (0.1B, 0.2B, 0.3B, 0.4B and 0.5B), then it is observed that upto depth 0.3B, 3Bx3B size of geotextile gives maximum improvement in bearing capacity and beyond 0.3B depth, 4Bx4B size of geotextile gives maximum improvement in bearing capacity.

Pressure cell was also placed below footing at depth of 1B and 2B to study the variation in pressure, when sand bed is reinforced with geotextile. The variations in pressure measured at 1B and 2B below footing, without geotextile and with geotextile are shown in Fig 10.

Table 5 Settlement reduction ratio (SRR) value

Size of geotextile	Depth of placing geotxtile	SRR Without prestressed	SRR With prestressed
2Bx2B	0.1B	1.72	2.19
	0.2B	1.99	2.82
	0.3B	1.87	2.58
	0.4B	1.59	2.05
	0.5B	1.46	1.87
3Bx3B	0.1B	2.14	2.64
	0.2B	2.54	3.14
	0.3B	3.40	4.24
	0.4B	2.31	2.99
	0.5B	1.90	2.63
4Bx4B	0.1B	1.49	2.26
	0.2B	2.10	3.24
	0.3B	2.66	3.63
	0.4B	2.02	2.70
	0.5B	1.84	2.56

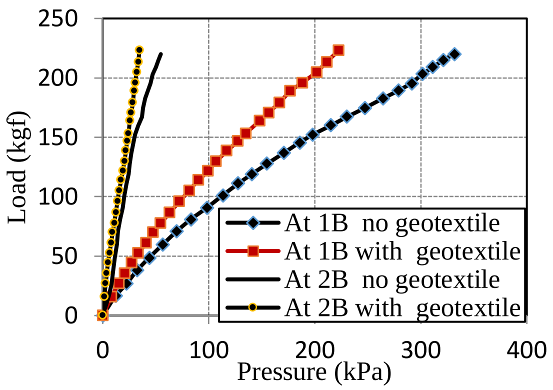

Fig.10 Load versus pressure cell reading

4. CONCLUSIONS

Based on the results obtained from experimental investigation, the following conclusion can be made for geotextile reinforced sand bed. Significant improvements are observed in load bearing capacity and settlement behavior of geotextile reinforced sand bed. The addition of prestress to geotextile gives further improvement. The improvement in bearing capacity depends upon size of geotextile and its placement depth below footing. The effect of reinforcement is significant up to depth 2B below footing.

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