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Under Axially Oblique Loading, Study of Small Scale Footing Load Tests on Randomly Distributed Fiber Reinforced Soil Foundations

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ABSTRACT

The expected advantages of fiber supported soil establishments over unreinforced sands exposed to slanted burdens are examined utilizing all out of 93 limited scope model balance load tests. The impact of soil support (level of filaments), impact of thickness of built up layer, impact of soil thickness and impact of burden tendency on some unmistakable boundaries like extreme bearing limit, vertical settlement and flat twisting are researched in this review. Test outcomes demonstrate that the utilization of fiber built up sand acquires impressive improvement extreme bearing limit, vertical settlement and flat disfigurement of establishment. A measurable model utilizing various straight relapse investigation dependent on present test information for anticipating the settlement (Sp) of square balance on built up sand at any heap applied was done where the reliant variable was anticipated settlement (Sp).

KEYWORDS: Inclined loading; Fiber reinforced sand; Square footing; Ultimate bearing capacity; Bearing capacity ratio; Vertical settlement ratio

INTRODUCTION

Footings which serve as foundations for retaining walls and framed structures may get subjected to other loads also in addition to the vertical load. Also for designing the foundations subjected to earthquake forces appropriate values of horizontal and vertical coefficients should be properly evaluated. The footings which are subjected to these types of loadings are resolved in two parts: (1) An eccentric vertical load and (2) An axially oblique load. In this study we are analyzing the footings which are subjected to only axially oblique load with the help of small scale footing load tests.

Randomly distributed fiber reinforced soil (RDFS) is among the latest techniques in which fibers of desired type and quantity are added in the soil, mixed and laid in position. The main advantage of randomly placed fibers is the absence of potential planes of weakness that can develop parallel to the oriented reinforcement.

Majority of work on RDFS is confined to triaxial tests [Andersland and Khattak (1979), Maher and Gray (1990), Al-refeai (1991), Michalowski and Zaho (1996), Ranjan *et al.* (1996), Charan (1996), Michalowski and Cermak (2002), Prabhakar and Sridhar (2002), Ahmad *et al.* (2010), Diambra *et al.* (2010)], with some tests on direct shear test [Fatani *et al.* (1991), Yetimoglu and Salbas (2003), Tang *et al.* (2010), Falorca and Pinto (2011)], unconfined compressive strength test [Maher and Ho (1994)], and few on CBR tests [Benson and Khire (1994), Charan (1996), Nataraj and McManis (1997), Kumar *et al.* (1999), Yetimoglu et al. (2005), Kumar *et al.* (2008)], model tests on footing [Consoli et al. (2003), Kumar et al. (2011)]. However in all these studies for model footing tests the load applied is concentric and generally strip footing is used.

A number of experimental studies on the subject of oblique loading have been conducted by several researchers using different type of reinforcement [Saran and Aggarwal, (1991), Patra *et al*., (2006), Saran *et al*., (2008)]. They studied the problem of generally strip footings reinforced with geogrid.

In the present study, small scale footing load tests have been performed on unreinforced soil and soil reinforced with randomly distributed polypropylene fibers to study the behavior of square footing subjected to axially oblique loading. Here the effect of thickness of reinforced soil layer, fiber percentage, relative density and angle of inclination on bearing capacity, vertical settlement and horizontal deformation have been studied in detail.

MODEL TESTING PROGRAM

Soil properties

The sand is classified as poorly graded sand (SP) by the Unified soil classification system with minimum and maximum density of 13.8 kN/m3 and 17.09 kN/m3 respectively, Cu and Cc of 2.09 and 0.98 respectively and specific gravity of 2.61.

Reinforcement properties

Corrugated polypropylene fibers "ENDURA HPP 45" with 45mm length and specific gravity of 0.91 were used as reinforcement throughout this investigation.

A plastic fabric sheet with maximum tensile strength of 8.46 kN/m is also placed at an interface of reinforced and unreinforced layer to act as a separator which also acted as reinforcing material.

Test series description

Total of Ninety-three model tests as described in Table 1, were conducted on square footing resting on unreinforced and reinforced sand subjected to axially oblique loading. The testing was conducted in three phases. Phase I is comprised of three tests conducted on totally unreinforced sand at three different inclination angles (i) of 5°,10° and 15° with the vertical compacted at 25% relative density (R_D). Phase II tests (18 tests) were designed to examine the effect and strength contribution on bearing capacity of plastic fabric sheet placed at interface of two different layers of unreinforced sand at three different thicknesses of sand layers (0.5B, 0.75B and 1B). Here the load is applied at three different inclination angles of 5°, 10° and 15° and the layer above plastic fabric sheet is compacted at two different relative densities (25% and 55%) underlain by unreinforced sand compacted at relative density of 25%. Phase III involved 72 tests conducted on a sand bed with top layer of sand reinforced with four different fiber percentages by weight of sand (0.5%, 0.75%, 1% and 1.25%) compacted at two different relative densities and underlain by unreinforced sand compacted at relative density of 25% with plastic fabric sheet placed at interface of reinforced and unreinforced sand at the different thicknesses of reinforced layer (0.5B, 0.75B and 1B).

Table 1: Detail of model tests conducted

Test no.	Conditions						
	Tank Conditions	h_1	h_2	R_{D1} in % (relative density of reinforced layer)	R_{D2} in % (relative density of unreinforced layer)	Angle of inclination to the vertical	Fiber %age
1-3	Only Sand	0	3B	25	25	5°, 10°,15°	0
4-21	Sand + Sheet	0.5B, 0.75B, 1B	2.5B, 2.25B, 2B	25, 55	25	5°, 10°,15°	0
22-93	Sand + Sheet + Fibers	0.5B, 0.75B, 1B	2.5B, 2.25B, 2B	25, 55	25	5°, 10°,15°	0.5%, 0.75%, 1%, 1.25%

Table 2: Bearing capacity ratios with top reinforced soil layer (h_1) compacted at relative

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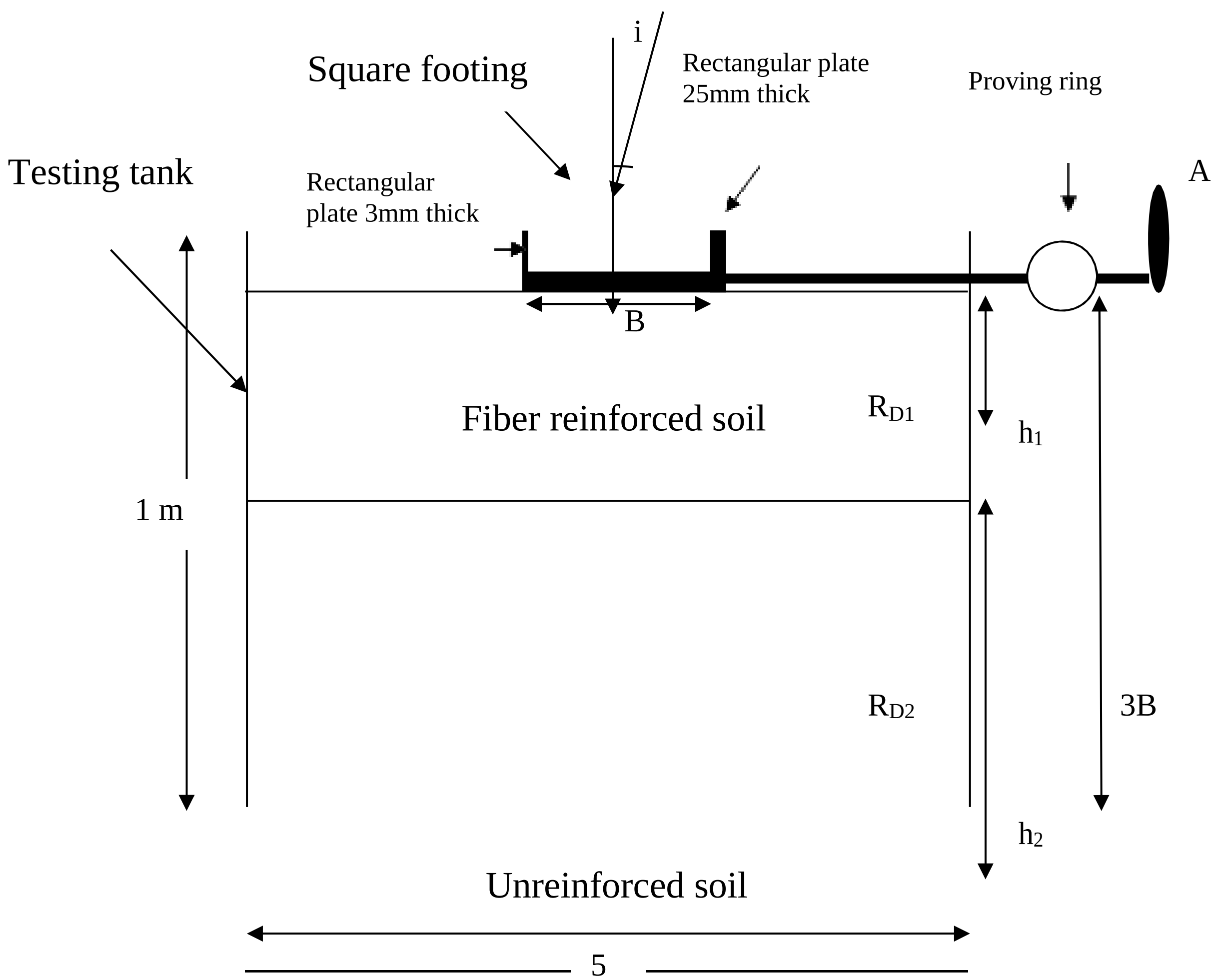
density of 25% for different angle of inclination of load to the vertical

Percentage fibers	BCR								
	i = 5°			i = 10°			i = 15°		
	0.5B	0.75B	1.0B	0.5B	0.75B	1.0B	0.5B	0.75B	1.0B
0% (Fabric sheet)	1.3	1.38	1.34	1.24	1.35	1.27	1.13	1.21	1.16
0.5%	2.26	3.3	4.15	2.17	3.66	4.85	2.11	4.14	5.63
0.75%	2.51	3.26	4.34	2.5	4.03	5.09	2.49	4.78	6.02
1%	2.8	3.72	4.51	2.88	4.21	5.29	3	4.93	6.25
1.25%	3.05	3.92	4.72	3.33	4.51	5.65	3.4	5.26	6.64

Test set up and procedure

All the ninety three tests were conducted on square footing subjected to axially oblique loading.Footings. Model square footing made up of mild steel plate of size 300mm by 300mm and thickness 25mm was used. Various standards have recommended a plate size varying from 300 mm to 750 mm for conducting the plate load tests (IS 1888:1982; BS 1377: Part 9:1990; ASTM D 1194 94).

A Rectangular plate of 4mm thickness was welded to one edge of footing for fixing a dial gauge to record horizontal deformation and another rectangular plate of 25mm thickness was welded to opposite edge of footing for the application of horizontal load (Fig. 1b).



A = Circular handle for the application of horizontal load

Figure 1 (a): Arrangement of Plate load tests

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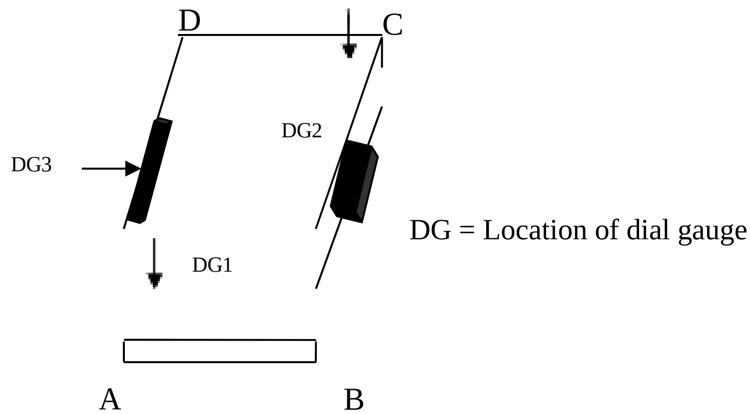

Figure 1 (b): Arrangement of dial gauges on model footing

Testing tank

All the model loading tests were conducted in a cubical steel tank of size 1.5m by 1.5m in plane and 1m in depth. The size of the tank was taken as 5 times the size of plate keeping in view the size of footing and zone of influence (IS: 1888-1982). The size of tank for conducting the model tests was decided by the size of footing and zone of influence. A hole was made in one side of tank to allow the passage of a horizontal steel rod for the application of horizontal load (Fig. 1a).

Loading assembly and load application

Vertical load (V_e) was applied to model footing by a hydraulic jack of capacity 25 Tonnes. Horizontal load (H) was applied simultaneously with the help of horizontal steel rod which is displaced by rotating the circular handle with which it is attached (Fig. 1b). A proving ring of capacity 50 kN was fixed in between the horizontal steel rod and circular handle. As the load applied is axially oblique, so for all the three inclination angles, the horizontal load to be applied was calculated from the vertical load applied and the angle of inclination of the load as $H=V_e \tan i$. After the application of each load increment, the cumulative load was maintained for a time interval of 15 minutes or until the vertical settlement has ceased or the rate of vertical settlement was reduced to a value of 0.02 mm/min (ASTM D 11194 94; IS 1888:1982).

Measurement of vertical settlement and horizontal deformation

Vertical settlement and horizontal deformation of the footing for each increment of the load applied were measured with the help of dial gauges. In order to record the vertical settlement of footing for each increment of load applied, two sensitive dial gauges were placed at opposite corners of square footing (shown in Fig. 1b) and their average was taken. The dial gauges were fixed to a reference beam and supported on external rods. The vertical load was applied in equal increments. To record the horizontal deformation of footing for each increment of load applied, a sensitive dial gauge was used. The plunger of the dial gauge was touched to the rectangular plate of width 4mm welded to the edge of the footing to record the horizontal deformation. For each load increment, measurement of vertical settlement and horizontal deformation was made.

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Placement of material

The test bed was prepared by placing the sand and fiber mixed sand in layers, each layer of 10cm thickness and compacted with the help of wooden rammer. To achieve the desired density, weight of sand and fiber mixed sand was calculated for 10 cm thick layer using the unit weight of sand and fiber mixed sand. The density 'ρ' of fiber reinforced soil mixture has been taken as $(W_f + W_s)/V$ which indicates that when fibers are added some sand is removed to keep the overall density constant. Here W_f is the weight of fiber; W_s is the weight of sand, ρ is density of fiber reinforced soil mixture and V is the corresponding volume.

Density was obtained by dividing weight by the corresponding volume.

Testing procedure

The model tests were conducted on the surface of totally unreinforced sand bed at relative density of 25%. Layers of Plastic fabric sheet were placed on the leveled surface of sand at the desired depths and the tests were conducted on the sand bed compacted at relative density of 25% and 55% above the plastic sheet and underlain by the sand compacted at original relative density. Later on, the footing was tested when the sand bed above the plastic fabric sheet is reinforced with different percentages of fibers and the load inclination with vertical is 5°, 10° and 15°.

The footing was placed on surface of leveled sand/sand fiber mixture. A proving ring was fixed to the horizontal rod which was further attached to the circular handle and this assembly is allowed to just touch the rectangular plate of 25mm thickness. The hydraulic jack is placed on the footing and the collar is just touched to the top of hydraulic jack and if required some adjusting plates are also placed.

The vertical load is applied with the help of hydraulic jack and the vertical settlement is recorded on the two dial gauges placed at opposite corners of the footing and their average was taken.

The horizontal load is applied simultaneously with the rotation of the circular handle and the applied load is measured through the proving ring and transferred from the horizontal rod to the footing and the horizontal deformation is recorded on the dial gauge placed on the edge opposite to the edge to which horizontal load is applied.

Vertical settlement and horizontal deformation were recorded when readings of the dial gauge became reasonably constant. The vertical settlement and horizontal deformation is recorded due to each load increment and then utilized for obtaining the pressure-vertical settlement and pressure-horizontal deformation curves.

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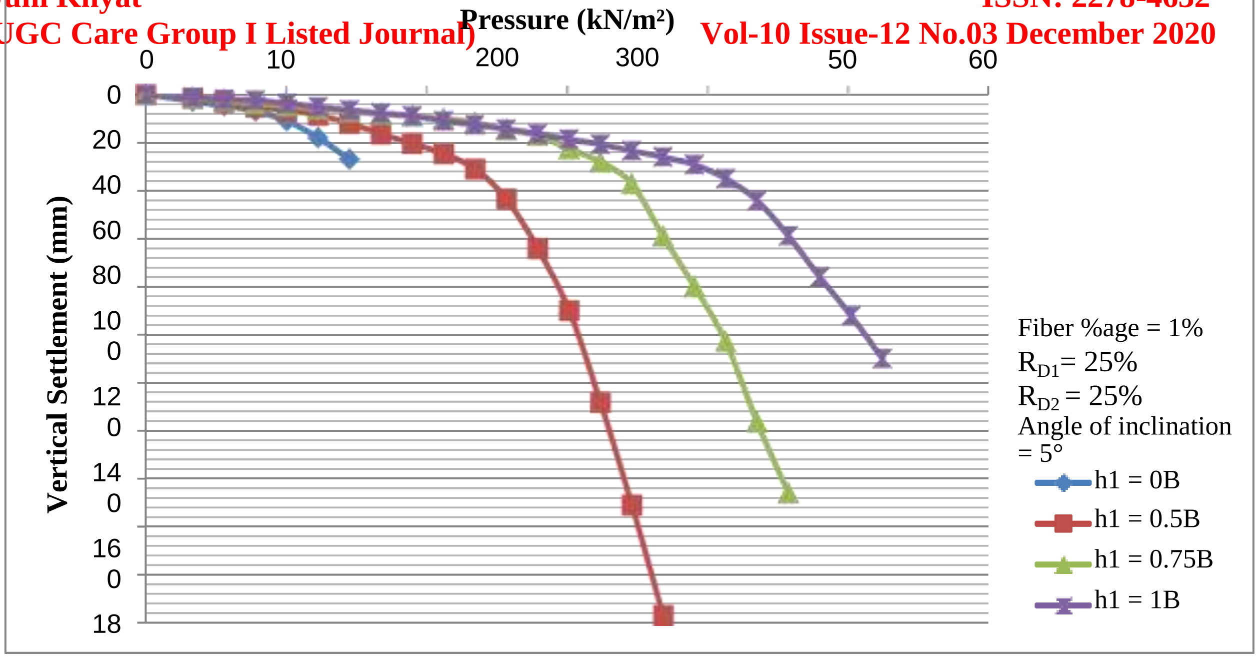

Figure 2: Pressure versus vertical settlement for the soil reinforced with 1.0% fiber

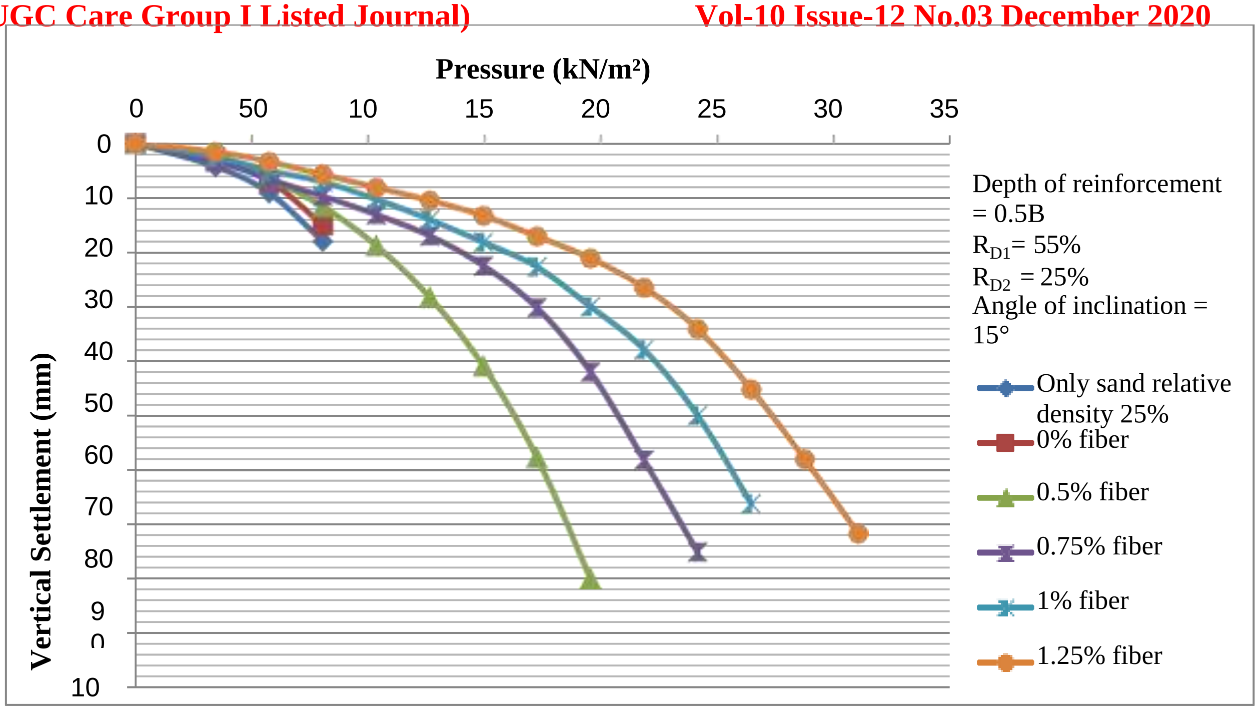

Figure 3: Pressure versus vertical settlement for the soil reinforced up to 0.5B thickness

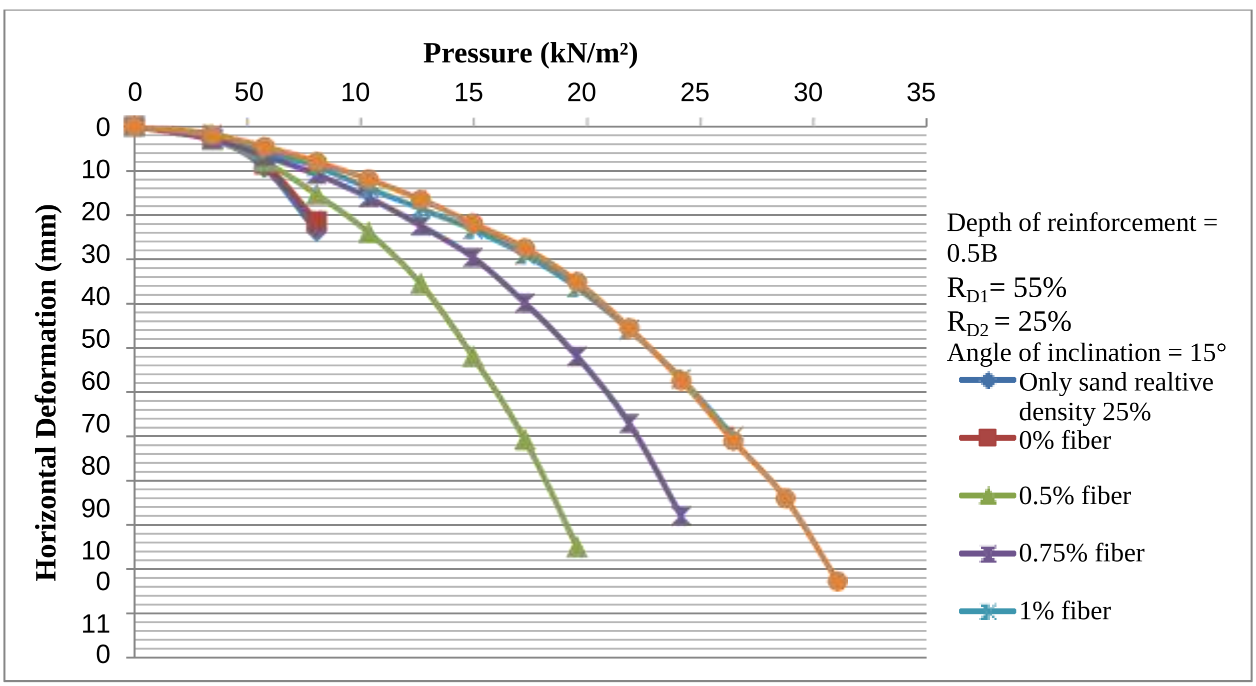

Figure 4: Pressure versus horizontal deformation for the soil reinforced up to 0.5B thickness

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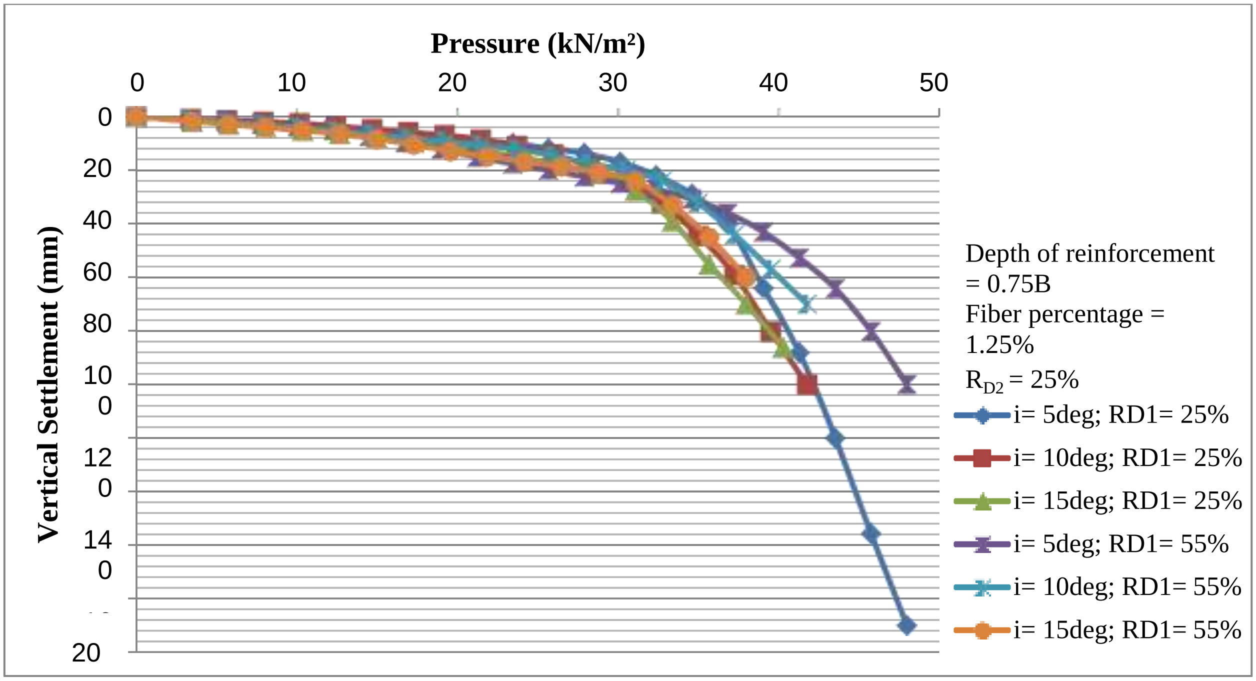

Figure 5: Pressure versus vertical settlement for the soil reinforced up to 0.75B thickness showing the effect of angle of inclination

EFFECTS OF THICKNESS OF REINFORCED SOIL LAYER

Pressure versus vertical settlement and pressure versus horizontal deformation curves were plotted for various setups and value of ultimate bearing capacity were calculated from these curves using double tangent method. The effect of thickness of reinforced soil layer on bearing capacity, vertical settlement ratio and horizontal deformation ratio are studied in this section.

Effect on bearing capacity

Analysis of the experimental results reveal that the value of ultimate bearing capacity and bearing capacity ratio increases with increase in thickness of reinforced layer, overlying poorly graded sand. Fig. 2 shows a pressure versus vertical settlement curve when top layer is reinforced with 1% fibers, compacted at 25% relative density and load is inclined at 5° to the vertical and reveals the same trend. When reinforced with 1% fibers, the ultimate bearing capacity of soil increases to 264 kN/m^2 from 94.26 kN/m^2 when the soil is reinforced up to 0.5 B thicknesses and it further increases to 350.7 kN/m^2 and 425.5 kN/m^2 when the soil is reinforced up to 0.75 B and

B respectively. Also Fig. 6 and 7 and Table 2 and 3 clearly show that the bearing capacity ratio increases with increase in thickness of reinforced layer. But after 0.75B thickness, the rate of increase of ultimate bearing capacity is small. As for example, when the top layer was reinforced with 1% fibers, with increase in thickness of layer from 0.5B to 0.75B, the value of ultimate bearing capacity increases by 33.3% and it further increases by 21.35% if thickness of top layer is increased from 0.75B to 1B.

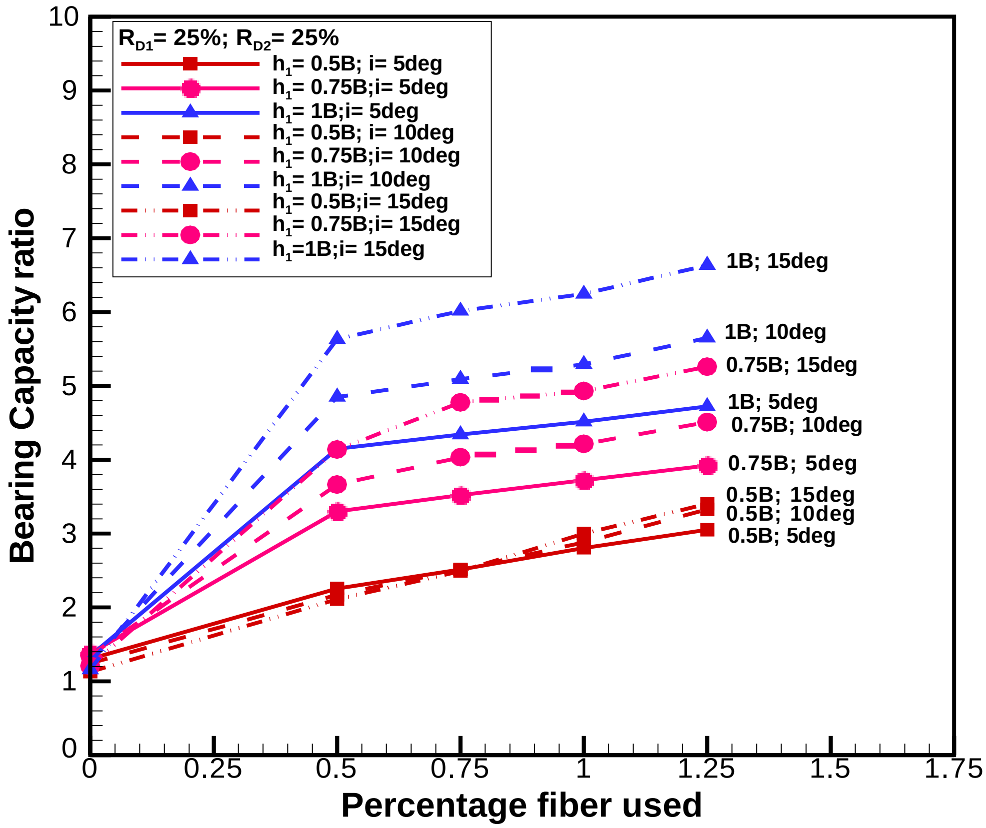

Figure 6: Bearing capacity ratio versus percentage of fibers with reinforced soil layer compacted at relative density of 25%

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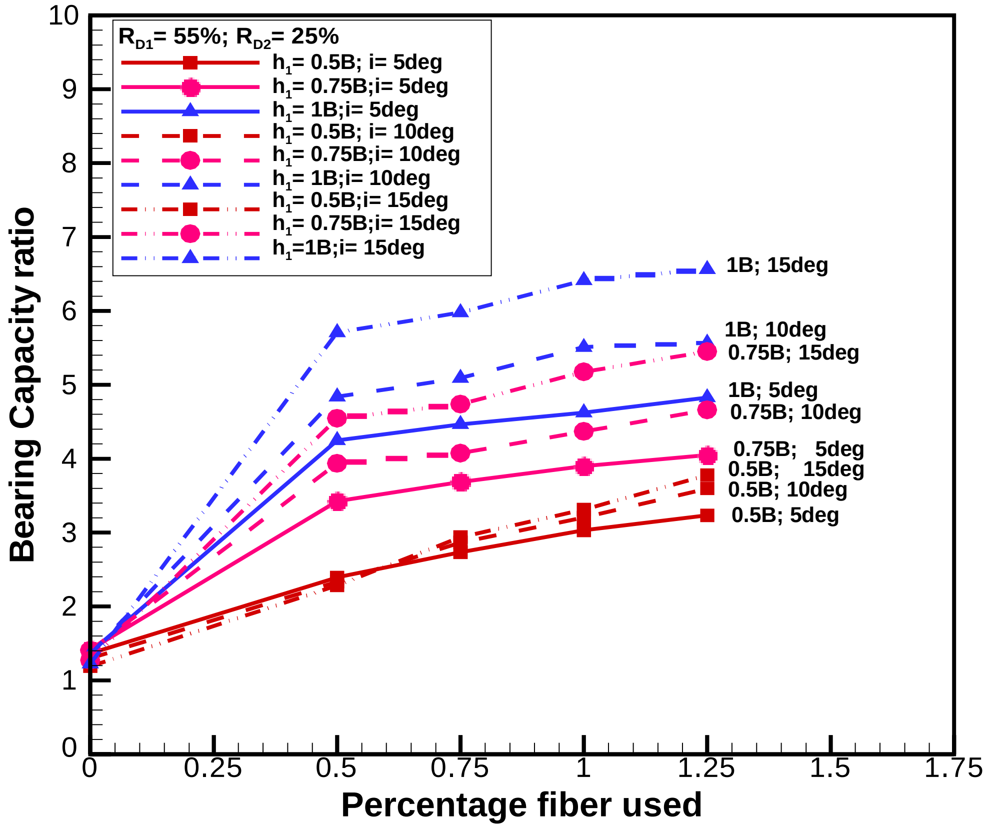

Figure 7: Bearing capacity ratio versus percentage of fibers with reinforced soil layer compacted at relative density of 55%

Effect on vertical settlement ratio (SR)

The vertical settlement decreases with increase in thickness of reinforced layer (Fig. 8 and 9 and Table 4 and 6). When load is inclined at 10° to the vertical and top layer is reinforced with 1% fibers and compacted at 25% relative density, the rate of decrease in vertical settlement increases with increase in thickness of reinforced layer. There is 11.3% and 13.66% decrease in vertical settlement ratio when the thickness of top reinforced layer is increased from 0.5B to 0.75B and 0.75B to 1B respectively.

Effect on Horizontal deformation ratio (HDR)

Results presented in Tables 5 and 7 clearly show that with the increase in thickness of reinforced layer there is decrease in horizontal deformation ratio. This trend can also be seen in Fig. 10 and 11. With increase in thickness of top reinforced layer from 0.5B to 0.75B and 0.75B to 1B, the horizontal deformation ratio decreases from 5.5 to 4.1 and 4.1 to 3.1 respectively when reinforced with 1.25% fiber and compacted at 25% relative density and load inclination is 10°.

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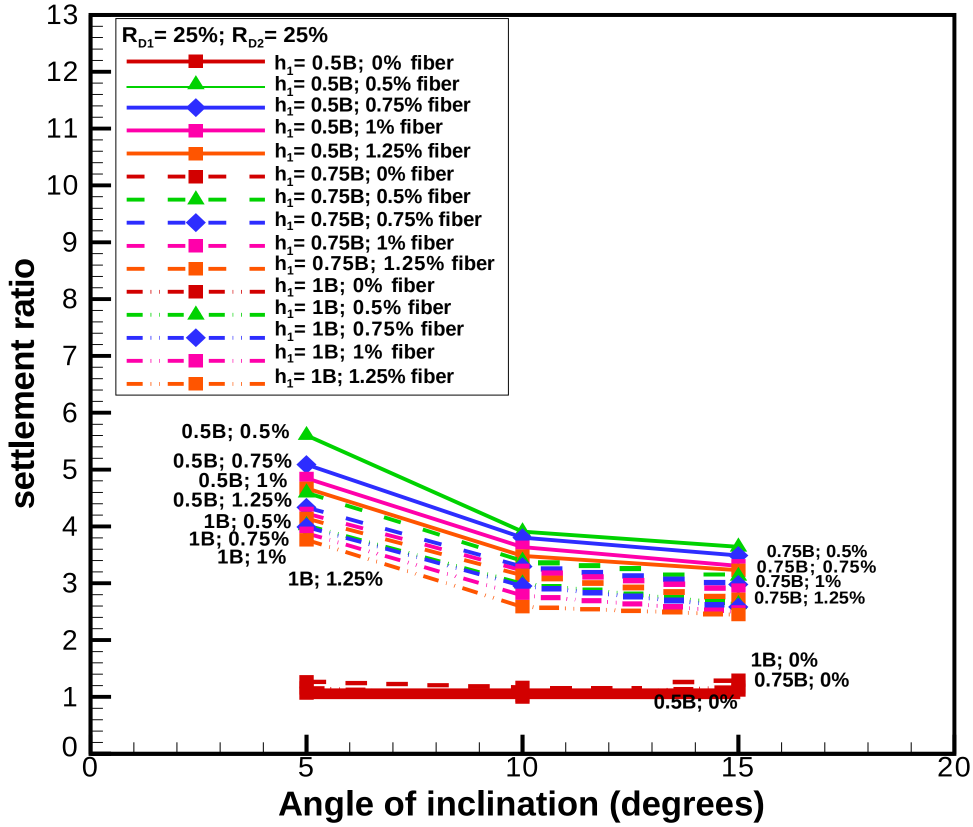

Figure 8: Vertical settlement ratio versus angle of inclination with reinforced soil layer compacted at relative density of 25%

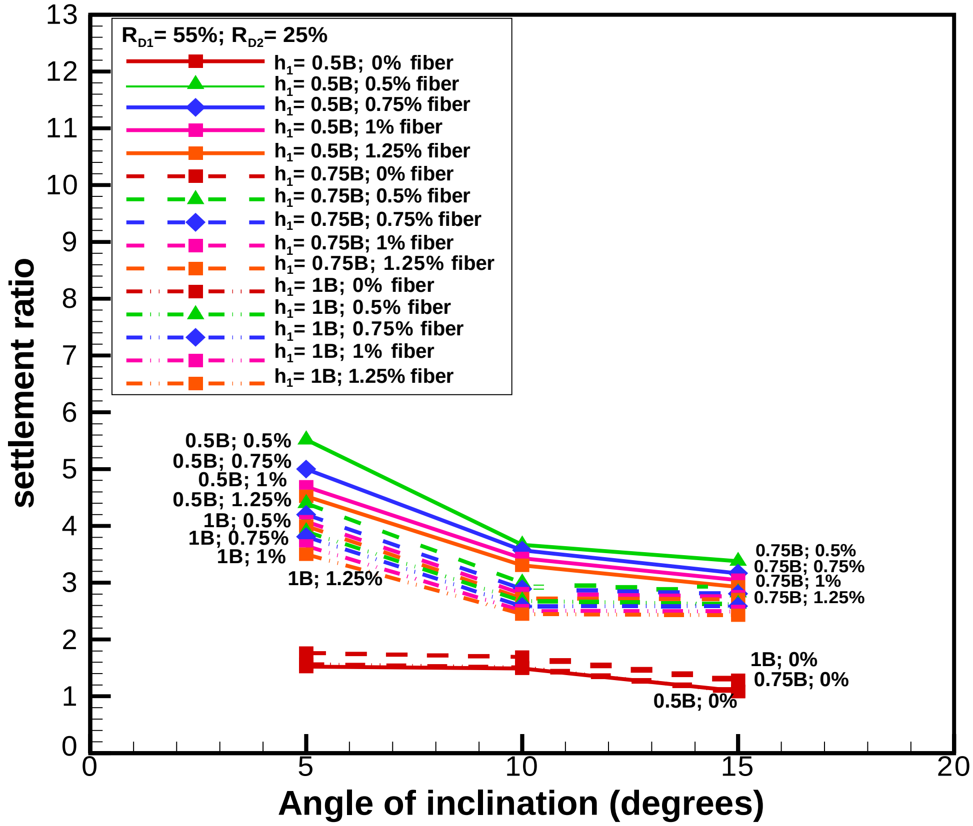

Figure 9: Vertical settlement ratio versus angle of inclination with reinforced soil layer compacted at relative density of 55%

EFFECTS OF REINFORCEMENT

As it has been already mentioned that the poorly graded sand was reinforced with two types of reinforcement (Fibers of different percentages and plastic fabric sheet), so it is necessary to study the effect of reinforcement together and individually. The fibers are added to the sand for the purpose of only reinforcing the material thus increasing its strength but the plastic fabric sheet fulfills two purposes; one as a reinforcement and other as a separator to separate the reinforced layer from the unreinforced layer so as to maintain the percentage of fibers in reinforced layer to the desired level. The top layer of poorly graded sand was reinforced with 0.5%, 0.75%, 1.0% and 1.25% randomly distributed fibers at different thicknesses and plate load tests were conducted on footing resting on reinforced sand overlying poorly graded sand. For the reinforced sand case, the ultimate bearing capacity calculated from these is the combined effect of plastic fabric sheet and percentage fiber. The individual contribution of plastic fabric sheet and fibers should also be computed. As the tests are also performed where only plastic fabric sheet is present, so to know the contribution of only fibers, first the BCR of sands reinforced with only fibers is calculated by dividing the BCR of sand reinforced with only plastic fabric sheet from the BCR of sand reinforced with randomly distributed fibers and plastic fabric sheet at the interface. Then, the ultimate bearing capacity of sands reinforced with only fibers is calculated by multiplying the BCR of sands reinforced with only fibers with ultimate bearing capacity of totally unreinforced sands.

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Effect on bearing capacity

With increase in percentage of fibers and keeping all other parameters same, experimental results reveal that there is increase in bearing capacity ratio. Fig. 3 shows the graphical representation of model test results when the thickness of top reinforced layer is taken as 0.5B and compacted at 55% relative density and the load applied is inclined at 15°. Here it is clearly seen that with increase in percentage of fibers there is increase in bearing capacity, but the gain is less when the fiber percentage is increased beyond 1%. For 0.5B thickness of reinforced layer and considering the effect of only fibers, there is 92%, 147%, 178.4% and 217.6% gain in terms of bearing capacity if the percentage fiber is increased to 0.5%, 0.75%, 1% and 1.25% respectively in comparison to totally unreinforced soil. The bearing capacity ratios are shown in Table 2 and 3 which shows the same trend. For 0.5B thickness of reinforced layer and considering the combined effect of fibers and plastic fabric sheet, there is 87.1%, 120.9%, 166% and 201.7% gain in terms of bearing capacity if the percentage fiber is increased to 0.5%, 0.75%, 1% and 1.25% respectively in comparison to the totally unreinforced soil compacted at R_D = 25%. Further, some plate load tests under concentric loading conditions were conducted (Kumar and Kaur, 2012) without providing plastic fabric sheet at the interface of reinforced and unreinforced layers. The test results show that the addition of fibers to soil is more effective if fiber reinforced soil layer is separated from the unreinforced soil with the help of plastic fabric sheet.

Also the pressure-vertical settlement and pressure-horizontal deformation curves were plotted after reinforcing the soil with plastic fabric sheet only for different depths of placement of plastic fabric sheet (0.5 B, 0.75 B and 1.0 B). From the results it is seen that the bearing capacity increases with increase in depth of plastic fabric sheet up to 0.75 B depths. But after 0.75B depth, with increase in depth of placement of fabric sheet there is decrease in ultimate bearing capacity (Tables 8 and 9). Similar results were observed by Consoli et al (2003), Kumar et al (2011) and Kumar and Kaur (2012).

The results showing the individual effect of plastic fabric sheet and fibers on ultimate bearing capacities are revealed in Tables 8 and 9.

From Tables 8 and 9, it is clear that:

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1. Ultimate bearing capacity of fiber reinforced soil increases with increase in percentage of fiber.

2. Ultimate bearing capacity of reinforced soil increases with increase in thickness of reinforced soil layer. But the rate of increase is less after 0.75B thickness of fiber reinforced soil layer.

3. The gain in ultimate bearing capacity of reinforced soil is more when top reinforced layer is compacted at relative density of 55% as compared to that compacted at relative density of 25%.

Effect on vertical settlement ratio

The vertical settlement decreases with increase in percentage of fibers used and this effect is clearly revealed in Fig. 3, 8 and 9 and Table 4 and 6. There is about 9.1%, 4.8% and 3.6% decrease in vertical settlement ratio when the amount of fibers used is increased from 0.5% to 0.75%, 0.75% to 1% and 1% to 1.25% respectively when the top reinforced layer is 15cm thick (0.5B) and compacted at 25% relative density and load is inclined at 5° to the vertical.

Effect on horizontal deformation ratio

With the increase in thickness of reinforced layer, there is decrease in horizontal deformation ratio but there are some cases as shown in Table 5 and 7 where the horizontal deformation thus the horizontal deformation ratio increased with the increase in percentage of fiber. This is because of the reason that these values are computed at ultimate loads as with increase in percentage of fibers used the ultimate bearing capacity value increases therefore failure is also at more load so horizontal deformation value can increase but at same bearing pressure the horizontal deformation surely decreases with increase in percentage of fiber. In terms of horizontal deformation ratio, the more gain is when percentage fiber is increased from 0.75% to 1% and it is clearly shown in Fig. 4. As for example when the top 1B thick reinforced layer is compacted at 25% relative density and applied load is inclined at 15°, there is about 3%, 18.8% and 2.4% decrease in horizontal deformation ratio when percentage fibers is increased from 0.5% to 0.75%, 0.75% to 1% and 1% to 1.25% respectively. Results are clearly shown in Table 5 and 7 and this trend can also be seen in Fig. 10 and 11.

EFFECTS OF LOAD INCLINATION

Model test results revealed that with the increase in the load inclination there is improvement in value of ultimate bearing capacity, vertical settlement and horizontal deformation (Table 2 to 9). Similar finding was reported by Saran et al (2008).

Effect on bearing capacity

With increase in angle of inclination to the vertical, the bearing capacity decreases but the bearing capacity ratio increases. The reason behind this finding is that the ultimate bearing capacity of totally unreinforced soils decreases with increase in angle of inclination so the dividing factor to compute the bearing capacity ratio is different for different angle of inclination of load and it decreases with increase in angle of inclination. For example, When the top 30 cm (1B) thick layer is reinforced with 1% fibers and compacted at 25% relative density, the bearing capacity decreases from 425.5 kN/m^2 to 372 kN/m^2 and 372 kN/m^2 to 355.5 kN/m^2 when angle of inclination increases from 5° to 10° and 10° to 15° respectively but the bearing capacity ratio increases from 4.5 to 5.29 and 5.29 to 6.25 when the inclination angle increases from 5° to 10° and 10° to 15° respectively (Fig. 8 and 9 and Table 2 and 3). The ultimate bearing capacity of total unreinforced soils is 94.26 kN/m^2, 70.31 kN/m^2 and 56.92 kN/m^2 when load is inclined at 5°, 10° and 15° respectively to the vertical.

Effect on vertical settlement ratio

The vertical settlement decreases with increase in angle of inclination and this effect is clearly revealed in Fig. 5, 8 and 9 and Table 4 and 6. When the top 22.5 cm (0.75B) thick layer is reinforced with 1.25% fibers and compacted at 25% relative density, there is about 31.8% and 14.5% decrease in vertical settlement ratio with increase in angle of inclination from 5° to 10° and 10° to 15° respectively. When the top 22.5 cm (0.75B) thick layer is reinforced with 1.25% fibers and compacted at 55% relative density, there is about 38.7% and 1.8% decrease in vertical settlement ratio with increase in angle of inclination from 5° to 10° and 10° to 15° respectively.

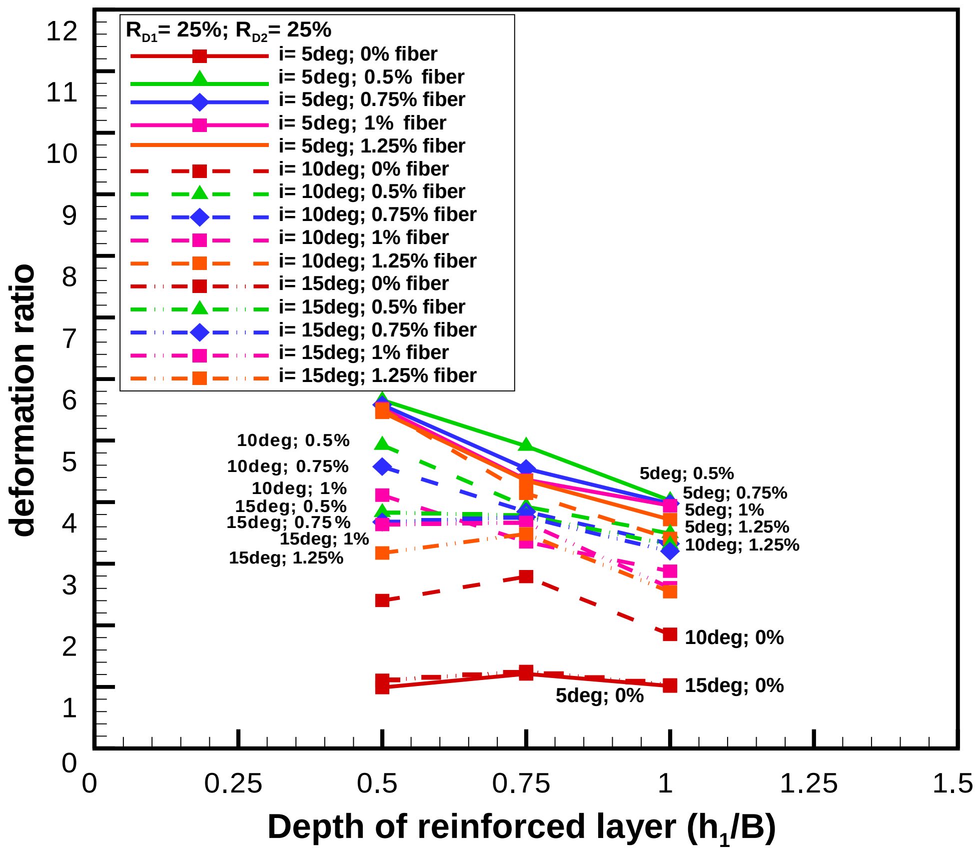

Figure 10: Horizontal deformation ratio versus thickness of reinforced layer with reinforced soil layer compacted at relative density of 25%

Effect on horizontal deformation ratio

With the increase in angle of inclination, there is increase in the horizontal deformation but decrease in horizontal deformation ratio in some cases and this effect is clearly revealed in Fig.10

and 11. The reason is same as explained in earlier. When the top 22.5 cm (0.75B) thick layer is reinforced with 0.75% fibers and compacted at 25% relative density, the horizontal deformation increases from 28.12mm to 30.83mm and 30.83mm to 33.16mm when angle of inclination increases from 5° to 10° and 10° to 15° respectively but the horizontal deformation ratio decreases from 4.54 to 3.84 and 3.84 to 3.67 when the inclination angle increases from 5° to 10° and 10° to 15° respectively (Fig. 10 and 11 and Table 5 and 7).

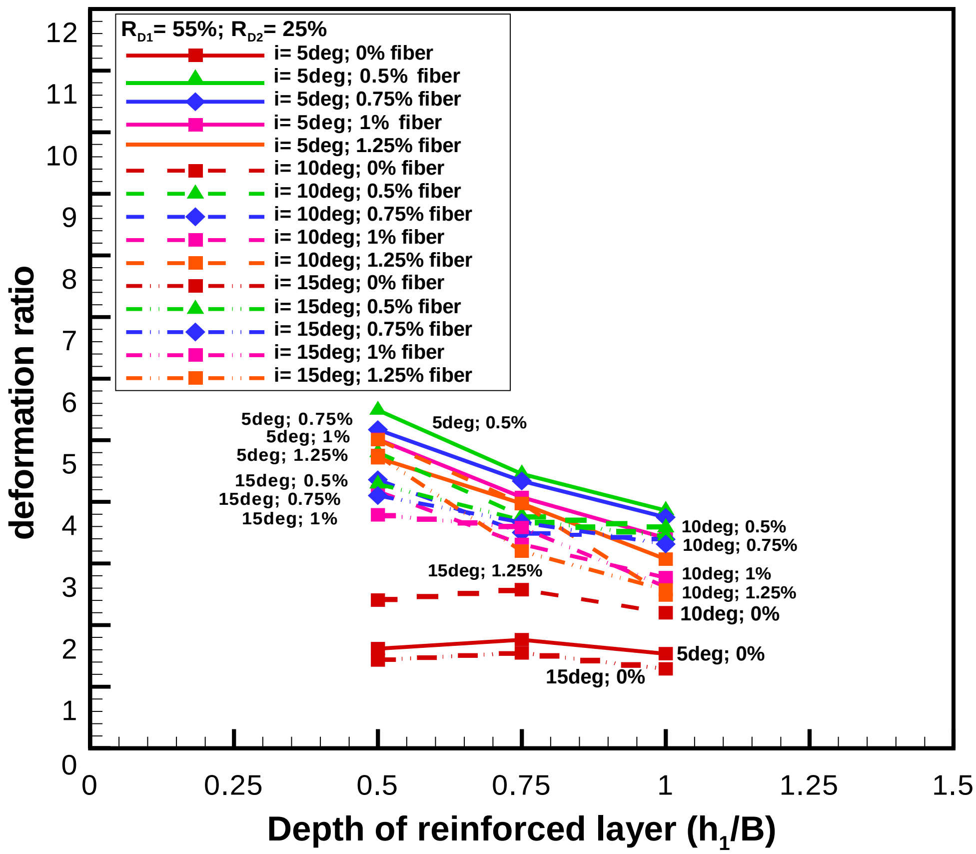

Figure 11: Horizontal deformation ratio versus thickness of reinforced layer with reinforced soil layer compacted at relative density of 55%

EFFECTS OF RELATIVE DENSITY OF SOIL

The plate load tests were conducted on footing resting on reinforced sand compacted at two relative densities of 25% and 55% overlying poorly graded sand having relative density of 25%. It is clear from the results discussed in Tables 2 to 9 that with increase in densification of soil there is improvement in terms of bearing capacity, vertical settlement and horizontal deformation.

Effect on bearing capacity

From the BCR results shown in Table 2 and 3, it is clearly seen that the increase in ultimate bearing capacity is about 5.3 times that of the virgin soil when soil is reinforced up to 1B with 1% of fibers below the base of footing compacted at 25% relative density when load is inclined at

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angle 10° and the ultimate bearing capacity of reinforced soil further increases to 5.51 times when compacted at 55% relative density under the same inclination of load.

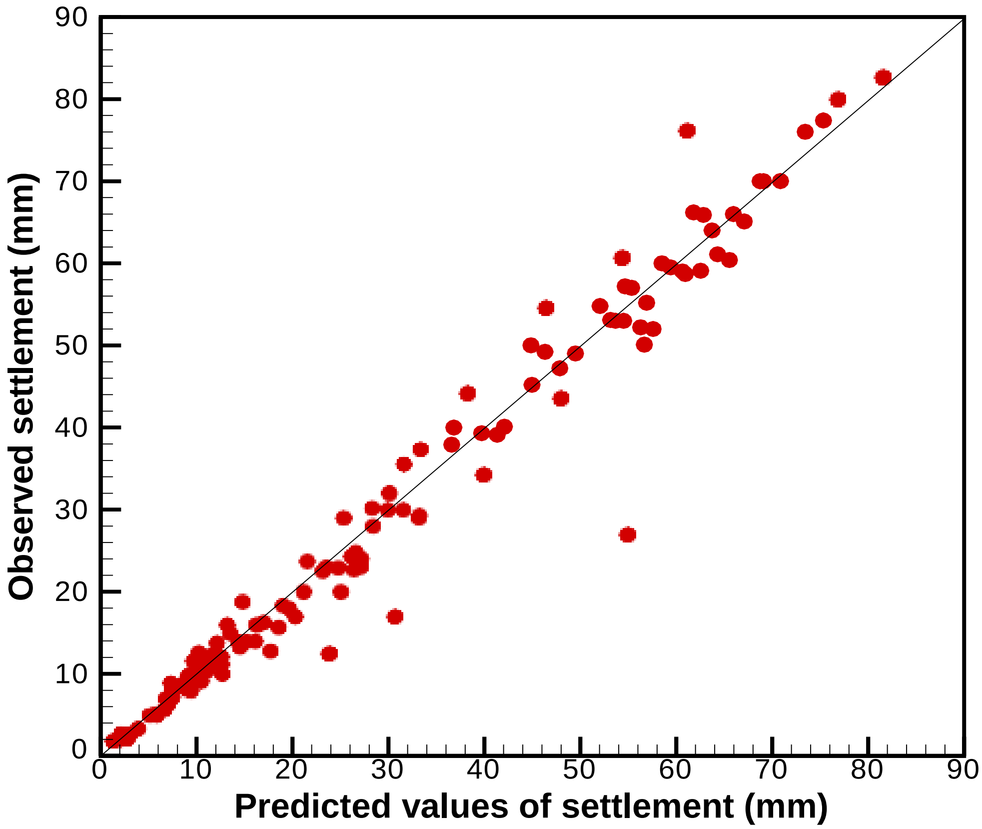

Figure 12: Linear scatter diagram showing the comparison between observed and predicted values of settlement

Effect on vertical settlement ratio

There is improvement in terms of vertical settlement ratio when the top reinforced layer is compacted at more relative density i.e., 55% relative density instead of 25% relative density and this effect is already explained in section 3.3.2.

Effect on horizontal deformation ratio

With increase in densification of top reinforced layer, there is improvement in terms of horizontal deformation. When the top 1B thick reinforced layer is compacted at 55% relative density and applied load is inclined at 15°, there is about 4.1%, 20.8% and 1.9% decrease in horizontal deformation ratio when percentage fibers is increased from 0.5% to 0.75%, 0.75% to 1% and 1% to 1.25% respectively. The results when top reinforced layer is compacted at 25% relative density is already explained in section 3.2.3 and by comparing these results it is clear that if density of soil is increased the gain in terms of horizontal deformation is more.

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STATISTICAL MODEL RESULTS

A statistical model has been developed based on present experimental data for predicting the settlement (S_p) of square footing on reinforced sand at any load applied. Multiple linear regression analysis was done where the dependent variable was predicted settlement (S_p). The various independent variables considered for regression analysis were as follows:

(i) Settlement of square footing on unreinforced sand at any pressure in mm (S_u)

(ii) Various pressure values in kN/m^2 (p)

(iii) Thickness of reinforced layer per unit width (h_1/B)

(iv) Relative density of reinforced sand layer (R_{D1})

(v) Percentage of fibers used (pf)

(vi) Angle of inclination of load applied (i)

The equation for predicted settlement values (S_p) obtained is given below

$$S_p = 43.36 - (0.5797*S_u) + (0.223*p) - (48.5*(h_1/B)) - (0.1177*R_{D1}) - (7.628*pf) - (0.45*i) \quad (7)$$

The value of relevant statistical coefficient like coefficient of determination, R^2 is found to be 0.62. The linear scatter diagram using the equation 7 is shown in Fig. 12, which shows that the observed and predicted values of settlement are matching very well. The same results are also presented in Table 10.

CONCLUSIONS

Ninety three small scale model tests were conducted to evaluate the benefits of fiber reinforced square footings and based on this study the following conclusions were drawn:

1. The BCR values increase with the increase in thickness of the reinforced layer but the rate of gain is less after 0.75B thickness and the SR values decrease with increase in thickness of the reinforced layer and this rate of decrease is more pronounced when thickness of reinforced sand layer is 1B.
2. With only plastic fabric sheet at 0.5 B below the base of the footing, the value of ultimate bearing capacity increases by 23.3%, 19.6% and 11.4% in comparison to the unreinforced soil at load inclination of 5°, 10° and 15° to the vertical. It further increases by 27.5%, 25.8% and 17.2% in comparison to the unreinforced soil with plastic fabric sheet at 0.75B at load inclination of 5°, 10° and 15° to the vertical. After which this effect goes on decreasing with the increase in depth of placement of plastic fabric sheet.
3. With the increase in percentage of fiber, there is improvement in terms of bearing capacity ratio, vertical settlement ratio and horizontal deformation ratio but the rate of improvement is very small if the percentage of fiber is increased beyond 1%.
4. The model test results show that the gain in bearing capacity of a square footing resting on sand after reinforcing the soil with randomly distributed fibers and fabric sheet at the interface is more when reinforced soil is compacted with high relative density i.e., 55%

as compared to the reinforced soil compacted at 25% relative density keeping all other parameters same.

5. There is good gain in terms of vertical settlement ratio and horizontal deformation when reinforced soil bed is compacted at more density i.e., 55% instead of 25% relative density.
6. A statistical model using multiple linear regression analysis based on present experimental data for predicting the settlement (S_p) of square footing shows that the observed and predicted values of settlement are matching very well.

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