BEARING CAPACITY OF FIBER REINFORCED SOIL

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ABSTRACT

Geotechnical engineers often encounter problems in designing foundations on highly compressible clayey soil due to its poor bearing capacity, low shearing strength, etc. Among various ground improvement techniques, nowadays in geotechnical engineering the idea of inserting fibrous material in the soil mass in order to improve its mechanical behavior has become very popular. In the present investigation the idea of using clayey soil as subsoil below footing using randomly distributed fibers, a series of laboratory model footing tests were conducted. The dosages of 12 mm length polyester fibers were taken as 0.25%, 0.50% and 1.00%. The results of load settlement curve of model footing test on un-reinforced soil and soil reinforced with various amount and depths of fiber reinforced soil were recorded. The results indicate that reinforcement of highly compressible clayey soil with randomly distributed fibers caused an increase in the ultimate bearing capacity and decrease in settlement at the ultimate load.

Keywords: Model Footing Test, Polyester Fibers, Soil Bearing Capacity, Soil Bearing Pressure

INTRODUCTION

The improvement in strength properties of soil has become one of the important tasks of geotechnical engineers due to scarcity of good sites, dramatic rise in land prices and increase in infrastructure growth. There are different improvement techniques to stabilize the poor ground in which soil reinforcement is an effective and reliable technique. The concept of soil reinforcement was first developed by Vidal (1969). He demonstrated that the introduction of reinforcement elements in a soil mass increases the shear resistance of the soil
The primary purpose of reinforcing soil mass is to improve its stability, increase its bearing capacity and reduce settlements and lateral deformation (Hausman-1990, Prabaker & Sridhar-2002). The investigations indicate that strength properties of fiber reinforced soils are the function of fiber content, fiber–surface friction along the soil mass and fiber strength characterises. (Hoare-1979, Gray & Ohashi-1983, Maher-1988, Ranjan et al.-1996, Kaniraj & Havanagi-2001, Praveenkumar & Swami-2008, Amet a-2009). The majority of currently published literature about randomly oriented fiber reinforcement deals with the reinforcement of cohesion less or granular soils. Only limited information has been reported on the use of randomly distributed discrete fibers for clayey soils in the literature. Most of the above studies on fiber reinforced soil were conducted on small scale such as C.B.R., unconfined compression, direct shear and triaxial tests etc. Very few studies were reported on influence of fibers on soil under model footing test. Thus an experimental programme using model footing test on larger scale has been undertaken on fiber reinforced clayey soil. To modify the engineering properties of highly compressible clayey soil, polyester fibers of 12mm size were used in the present study.

EXPERIMENTAL PROGRAMME

Soil Sample Used

For the present study, soil samples blackish in colour were collected from the Bhal Chandra Industry, Dabhoi, Baroda. As per Unified Soil Classification System, the soil sample was classified as CH. The liquid and plastic limits of soil were measured to be 53 and 27 respectively. The compaction curves developed by the standard proctor compaction tests show that the soil has a maximum dry unit weight of 16.50 kN/m$^3$ and optimum moisture content of 16.23%.

Soil Reinforcement Used

Polyester fibers of 12mm size used for the present investigation were supplied by Reliance Industries limited. The properties of fibers are listed as: type = Polyester, cut length = 12.1mm, cross section = triangular, diameter = 30 – 40 µm, tensile elongation = >100%, specific gravity = 1.34-1.39, tensile strength = 400 – 600 N/m$^2$. Due to triangular cross section fibers are better bonded with clay particle.

Model Footing Tests

Model footing tests on square footing having of size 100mm were conducted in the square steel tank of size 750mm X 750mm X 600mm (deep). The dimensions of tank were kept more than three times the size of the footing so that it should not include any boundary effects. The thickness of walls of the tank was kept enough to withstand lateral expansion under the loads. The model footing was made of cast iron for maintaining the perfect rigidity and the base of the footing was made rough for simulating the roughness of actual footing. The inside of tank was marked at every ten cm. The un-reinforced and fiber reinforced soil was layered at every 50mm thickness at MDD and OMC and compacted using the circular tamper of size 150mm for achieving required density. To maintain the uniformity, MDD and OMC for un-reinforced and fiber reinforced soil were kept constant. Total thirteen tests, one
on un-reinforced soil and twelve on fiber reinforced soil were conducted. Twelve tests on fiber reinforced soil were conducted with the combination of fiber content (0.25%, 0.50% and 1.00%) and depth of fiber reinforced soil (b/8=12.5mm, b/4=25mm, b/2=50mm and b=100mm, Where b is the size of footing.) Footing was placed in the middle of the tank after removing top 50mm layer for achieving proper compaction. Before starting the test a seating load of 7 kN/m$^2$ was applied. The load was applied and increased with an increment of about one tenth of estimated ultimate load. When the rate of settlement reduced to 0.01 mm per minute the next incremental load was applied. Before starting the new test, the soil in the tank was removed to a depth more than three times the size of the footing (Due to the analogy of pressure bulb soil is significantly affected the footing).

RESULTS AND DISCUSSIONS

The load settlement curves for un-reinforced clayey soil and for various combination of fiber reinforced soils on arithmetic scale are as shown in Figures 1-7. In these figures the failure point is not well defined hence the load settlement curves were prepared on logarithmic scale. The logarithmic graph gives two straight lines, intersection of these was considered as ultimate bearing capacity. Figures 1-7 shows that the load settlement curves for fiber reinforced soil are above than that of un-reinforced soil. In Figures 1-3, the load settlement curve for clayey soil mixed with fibers having a depth of 25mm (b/4) is above than that of 12.5mm (b/4), 50mm (b/2) and 100mm (b). In Figures 4-6, the load settlement curve for fiber reinforced clayey soil having fiber content 0.50% is above than with other fiber contents.

**Fig. 1** Load settlement curve for un-reinforced and fiber reinforced soil having fiber content 0.25%

**Fig. 2** Load settlement curve for un-reinforced and fiber reinforced soil having fiber content 0.50%
**Fig. 3** Load settlement curve for unreinforced and fiber reinforced soil having fiber content 1.00%

**Fig. 4** Load settlement curve for unreinforced and fiber reinforced soil having 12.5mm depth of fibers

**Fig. 5** Load settlement curve for unreinforced and fiber reinforced soil having 25.0mm depth of fibers

**Fig. 6** Load settlement curve for unreinforced and fiber reinforced soil having 50.0mm depth of fibers
Fig. 7 Load settlement curve for un-reinforced and fiber reinforced soil having 100.0mm depth of fibers

The soil bearing capacity (SBC) and soil bearing pressure (SBP) for un-reinforced clayey soil and fiber reinforced clayey soils are listed in Table 1. The SBP is calculated considering the width of footing 2.0 m and allowable settlement of footing 25mm. The least of SBC and SBP is considered as an allowable bearing capacity of foundation. Table 1 indicates that allowable SBC increases with increase in fiber content up to 0.50%. Beyond that with further inclusion of fibers it decreases. The SBC and SBP of un-reinforced soil are found to be 96.0 kN/m² and 62.5 kN/m². The allowable SBC increases as the depth of fiber reinforced soil increases. But maximum increase in allowable SBC is found when the depth of fiber reinforced soil increases from B/8 to B/4. There is no significant increase in SBC for the depth of fiber reinforcement beyond B/4. Thus optimum SBC was found at 0.50% fiber content with 25mm (b/4) fiber depth.

Table 3 Summary of SBC for unreinforced and fiber reinforced soil

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<thead>
<tr>
<th>Fiber Content, %</th>
<th>Depth of Fiber Reinforcement, mm</th>
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<tbody>
<tr>
<td></td>
<td>B/8 (12.5mm)</td>
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<tr>
<td>SBC, kN/m²</td>
<td>SBP, kN/m²</td>
</tr>
<tr>
<td>0.25%</td>
<td>93</td>
</tr>
<tr>
<td>0.50%</td>
<td>105</td>
</tr>
<tr>
<td>1.00%</td>
<td>85</td>
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CONCLUSIONS

There is a significant increase in bearing capacity of highly compressible clayey soil with the inclusion polyester fibers. The SBC increases with the inclusion of polyester fiber content up to 0.50%. The SBC increases as the depth of placement of fiber reinforcement increases. But the remarkable increase was observed when the depth of placement of fiber reinforcement increases from B/8 to B/4. There is lesser increase in the SBC found for the depth of placement of fiber reinforcement increases beyond B/4 depth. The allowable SBC for un-reinforced clayey soil is 62.5 kN/m$^2$ which increases to 190 kN/m$^2$ for fiber reinforced clayey soil for 0.50% fiber content and the depth of placement of fiber reinforcement of B/4.

REFERENCES