New Technique for Ground Improvement for Road and Building Construction

Kalpana Maheshwari, Dr. Atul Desai & Dr. C. H. Solanki
S V National Institute of Technology, Surat, Gujarat, India

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ABSTRACT
An experimental program was undertaken to study the effect of randomly distributed fibers on the strength properties of highly compressible clayey soil. Improvement in the strength properties of subsoil containing clayey soil used for road construction was obtained by conducting series of laboratory California Bearing Ratio (CBR) test. Series of model footing test was also performed to check the effectiveness of fiber reinforced soil for foundation of buildings. For these study highly compressible clayey soil having CH group and polyester fibers of 6mm and 12mm fiber length were used. It was observed that there is significant increase in CBR value of clayey soil with the inclusion of polyester fibers and due to these increase total thickness of subgrade reduce for the flexible pavement. The results of footing test indicate that due to fiber inclusion there was an increase in the ultimate bearing capacity and reduction in the settlement.

1 INTRODUCTION

In developing countries the biggest problem is availability of land and finance for construction of various civil engineering structures like roads and buildings. Use of local material, including local soils can considerably lower down the construction cost. But if local available soil consists of week soft clay then construction may cause differential settlement due to poor engineering soil properties. These local soils can be stabilize by various ground improvement techniques, either mechanically or chemically, but all of them require skilled man power and equipment to ensure adequate performance. Now a day's reinforcing the soil using the fibers is a reliable and effective technique and yet not well known. The nature is the best example of earth reinforcement. In the nature the roots of plant and trees hold the earth during heavy rain and cyclone.

Reinforced soils can be obtained by either incorporating continuous reinforcement inclusions (e.g., sheet, strip or bar) within a soil mass in a certain pattern (i.e., systematically reinforced soils) or mixing discrete fibers randomly with a soil fill (i.e., randomly reinforced soils). In comparison with systematically reinforced soils, randomly distributed fiber reinforced soils exhibit some advantages. Preparation of randomly distributed fiber reinforced soils mimics soil stabilization by admixture. Discrete fibers are simply added and mixed with the soil, much like cement, lime, or other additives. Randomly distributed fibers offer strength isotropy and limit potential planes of weakness that can develop parallel to oriented reinforcement.

2 LITERATURE SURVEY

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 matrix. 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 and Sridher, 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; Andersland and Khattak, 1979; Gray and Ohashi, 1983; Maher, 1988; Ranjan et al., 1996; Nataraja and Mcmanis, 1997; Kaniraj and Havanagi, 2001; Yestimoglu and Salbas, 2003; Gupta, 2008; Ameta, 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.

So in the present study to known the effect of fiber content for the stabilization of sub grade of roads series of CBR test were conducted. Also model footing test on large scale has been undertaken to check the suitability fibers for foundation of small buildings with the idea of upgrading the engineering behaviour of clayey soil as a sub soil for foundation.

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3 EXPERIMENTAL PROGRAMME

3.1 Collection of Soil Sample

For the present study, Soil samples blackish in colour were collected from the Bhal Chandra Industry, Dabhoi, Baroda.

3.2 Preliminary Tests

In preliminary tests, all the tests as mentioned in Table 1 were conducted as per relevant Indian Standards. The engineering properties of soil are listed in Table 1.

3.3 Soil Reinforcement Used

Polyester fibers of 6mm and 12mm size used for the present investigation were supplied by Reliance Industries limited. The product specifications and photographs of loose fibers are given in Table 2 and Figure 1 respectively.

Table 1. Characteristics of clayey soil used.

Properties	Values
Specific gravity	2.444
Gravel (%)	1
Sand (%)	8
Silt (%)	66
Clay (%)	25
Liquid limit (%)	52.9
Plastic limit (%)	27.5
Plasticity index (%)	25.7
Shrinkage limit (%)	23.5
IS classification	CH
Maximum dry density, gm/cc	1.65
Moisture content (%)	16.23

Table 2. Physical and engineering properties of fibers

Type	Polyester
Cut length	12.1 mm
Cross – length	Triangular
Diameter	30-40 μm
Tensile elongation	>100 %
Specific gravity	1.34 – 1.39
Tensile strength	400 – 600 N/m^2
Colour	Almost colourless

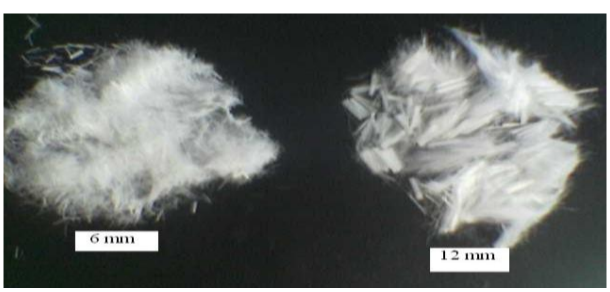

Figure 1. Photograph showing loose 6mm and 12mm Polyester fibers

3.4 California Bearing Ratio Test

To study the effects of adding polyester fibers on the strength characteristics of highly compressible clay soil for sub grade CBR tests were conducted. The amount of fiber content were varies from 0 to 3 %(by weight of dry soil). The Polyester fibers are mixed in dry soil by manually till it homogeneously mixed with soil. Both un reinforced and fiber reinforced soil is compacted at same MDD and OMC for maintaining uniformity. The CBR tests were conducted inside a modified proctor mould at soaked state per ASTM D1883-92. The mould was a rigid metal cylinder with an inside diameter of 152mm and a height of 178 mm. A manual loading machine equipped with a movable base that traveled at a uniform rate of 1.27 mm/min and a calibrated load indicating device was used to force the penetration piston with a diameter of 50mm into the specimen. The loads were carefully recorded as a function of penetration up to a total penetration of 30mm to observe the post-failure behaviour as well.

3.5 Results and Discussion of California Bearing Ratio Test

Figure 2 shows the effect of inclusion of polyester fibers of various cut lengths on soaked CBR Value of highly compressible clay mixed in different proportion of fiber. The soaked CBR Value of un reinforced soil is 0.75 % that for fiber reinforced soil having 1.5 % 6mm and 12mm fiber length is 5.03 % 5.15 % respectively.

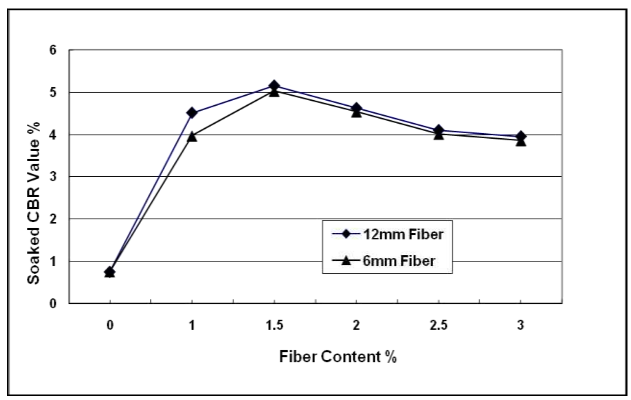

Figure 2. Relationship between soaked CBR value and fiber content

Figure 3 shows % increase in soaked CBR Value with different % of fiber. The increase in CBR Value is 570.67 % with the inclusion of 1.5 % 6mm size fibers. The increase is 586.67 % with the inclusion of 1.5 % 12mm size fibers.

3.6 Results and Discussion of California Bearing Ratio Test

Based on the laboratory results, CBR value for highly compressible clay is 0.75% and that for clay mixed with mixed with 1.5 % fiber with 12mm & 6mm length is around 5 %. As per IRC – 37 – 2001, design of flexible pavement for sub grade on both the soil was carried out. The total thickness of sub grade for un reinforced soil for traffic volume of 10msa was found to be 850 mm and that for fiber reinforced soil was found to be 660 mm.

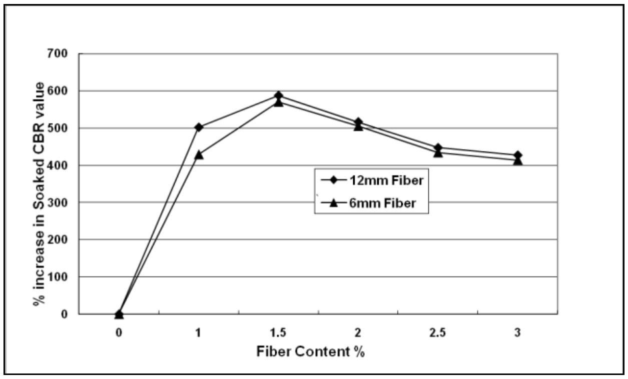

Figure 3. Relationship between % increase in soaked CBR value for various fiber content

3.7 Model Footing Test

Model footing tests on square footing having size 100mm and 150mm were conducted on 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 ten tests, one on un reinforced soil and nine on fiber reinforced soil on square plate of size 100 mm were conducted. Nine 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/4=25mm, b/2=50mm and b=100mm, Where b is the size of footing.) From these nine combinations of fiber reinforced soil for which SBC was found to be optimum, with that combination model footing was also conducted using the square plate of 150mm size. 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 70 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).

3.8 Results and Discussion of Model Footing Test

Figures 4-9 shows that the load settlement curves for fiber reinforced soil are above than that of un reinforced soil. In Figures 4-6, the load settlement curve for clayey soil mixed with fibers having a depth of 25mm (b/4) is above than that of 50mm (b/2) and 100mm (b). In Figures 7-9, the load settlement curve for clayey soil mixed with fibers having fiber content 0.50% is above than that having up to 0.25% and 1.00%. The SBC for un reinforced clayey soil and fiber reinforced clayey soils the same are listed in Table 3. Table 3 shows that SBC increases with increase in fiber content up to 0.50% and then starts decreasing with further increase in fiber content. Similarly SBC is found to be maximum when the depth of fiber reinforced soil is 25mm (b/4) after that SBC decreases with increase in fiber depth beyond 25mm (b/4).

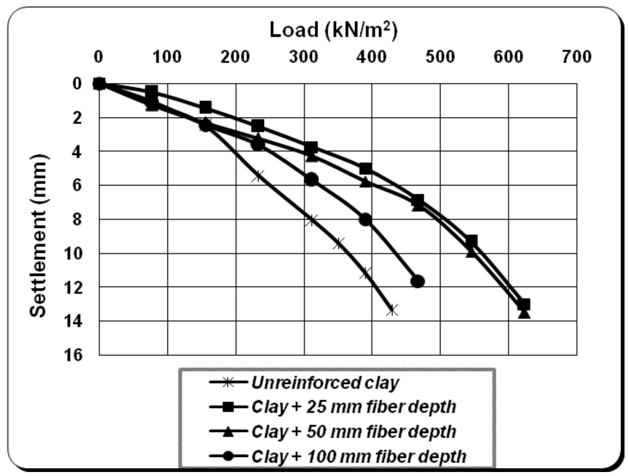

Figure 4. Load settlement curve for unreinforced and fiber reinforced soil having fiber content 0.25%

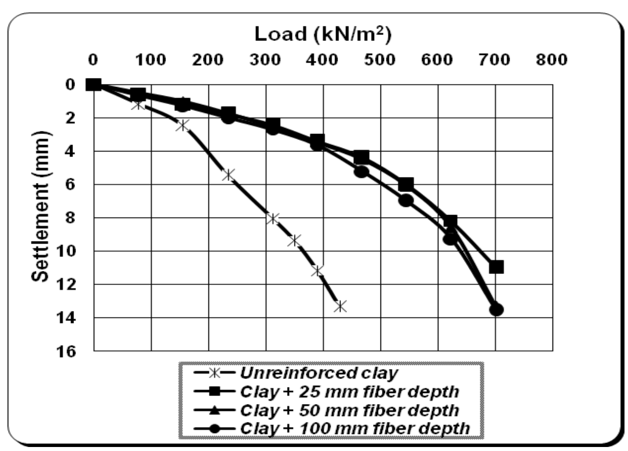

Figure 5. Load settlement curve for unreinforced and fiber reinforced soil having fiber content 0.50%

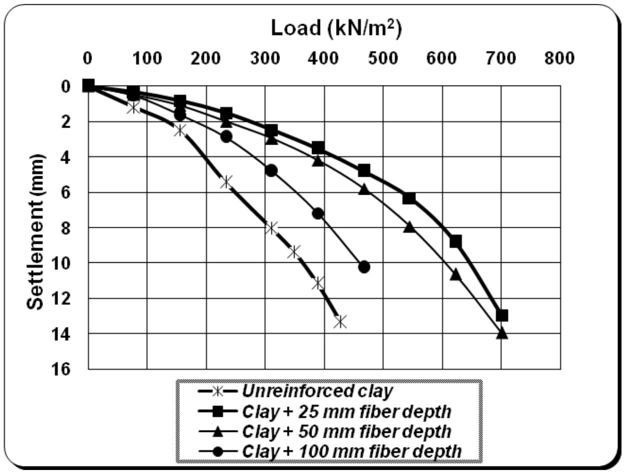

Figure 6. Load settlement curve for unreinforced and fiber reinforced soil having fiber content 1.00%

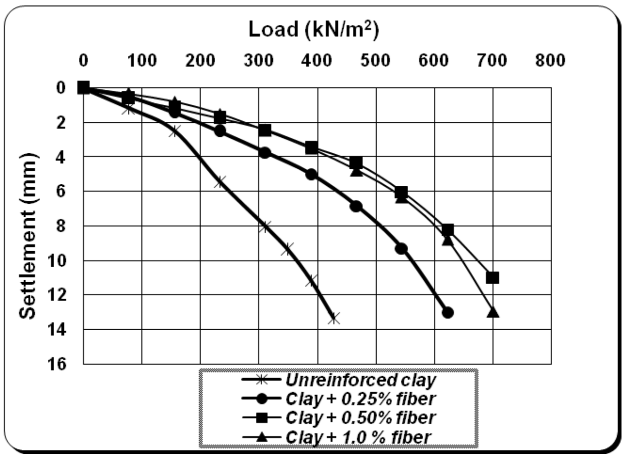

Figure 7. Load settlement curve for unreinforced and fiber reinforced soil having depth of fiber reinforced soil 25mm

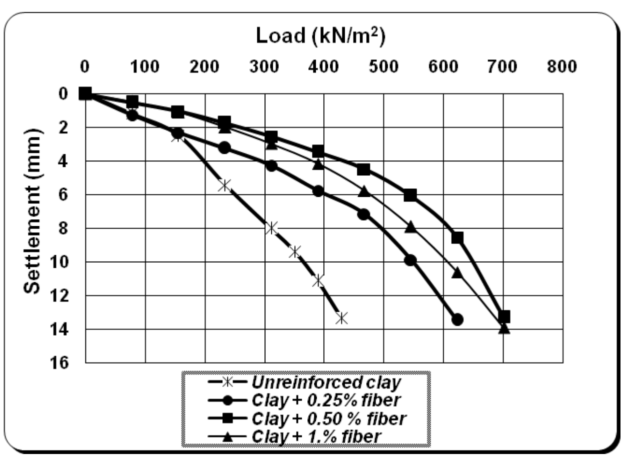

Figure 8. Load settlement curve for unreinforced and fiber reinforced soil having depth of fiber reinforced soil 50mm

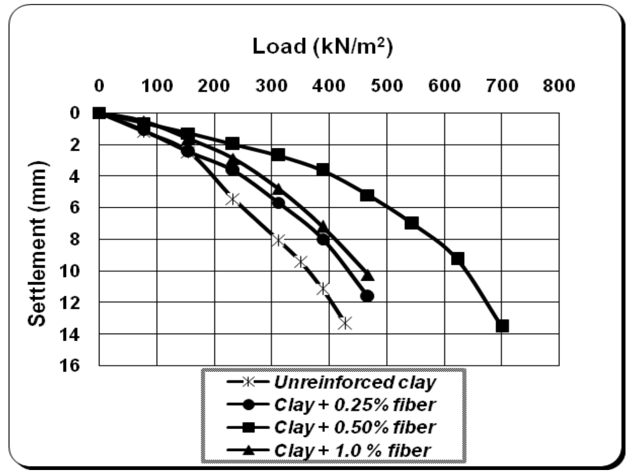

Figure 9. Load settlement curve for unreinforced and fiber reinforced soil having depth of fiber reinforced soil 100mm

Table 3. Summary of SBC for unreinforced and fiber reinforced soil

Fiber Content	SBC in kN/m^2 Depth of fiber reinforced soil b/4 (25mm)	 b/2(50mm)	 b(100mm)
0.25%	190	172	130
0.50%	220	200	140
1.00%	152	140	124.4

The settlements were also calculated at ultimate bearing capacity for various fiber content and various depth of fiber reinforced soil which were shown in Figure 10 and 11. Figure 10 shows that settlement decreases with increase in fiber content upto 0.50%. After that with increase in fiber content beyond 0.50% there was slight decrease in the settlement at ultimate bearing capacity. Figure 11 shows that settlement is minimum for 25mm (b/4) depth of fiber reinforced soil. Thus maximum SBC was observed at 0.50% fiber content with 25mm (b/4) depth of fiber reinforced soil.

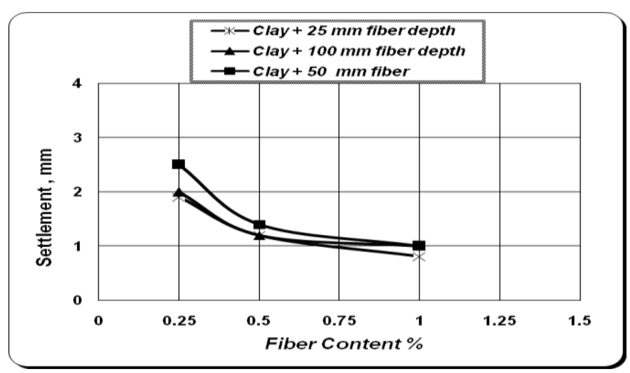

Figure 9. Settlement at ultimate bearing capacity versus fiber content

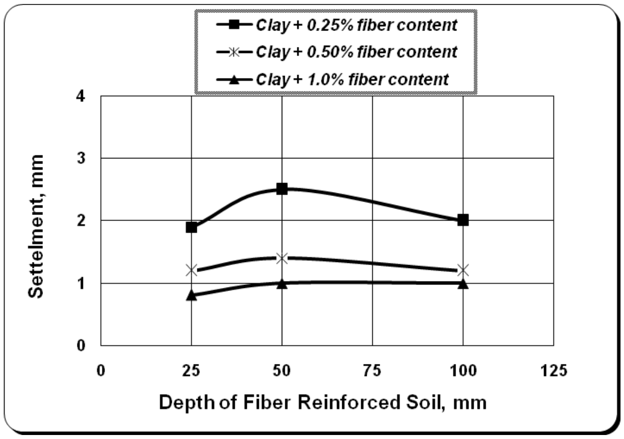

Figure 10. Settlement at ultimate bearing capacity versus depth of fiber reinforced soil

4 CONCLUSIONS

Following conclusions are drawn from the above study.

- There is a significant increase in California Bearing Ratio (CBR) and bearing capacity with the inclusion of polyester fiber in highly compressible clay.
- The soaked CBR increase with inclusion of polyester fiber up to (12mm & 6mm size) 1.5% fiber content and then decrease. So there is no significant effect with addition of polyester fiber beyond 1.5%.
- The percentage increase in soaked CBR Value is 570.67% & 586.67% with the inclusion of 1.5 % 6mm & 12mm size fiber respectively.
- The inclusion of 12mm 1.5% fiber in highly compressible clay reduces the total pavement thickness of sub grade from 850mm to 660mm.
- The SBC of unreinforced clayey soil was found to be 62.4 kN/m^2. The SBC was found 220 kN/m^2 for fiber reinforced soil having optimum fiber content of 0.50% and optimum depth of fiber reinforced soil b/4.
- Though the soil is significantly affected for a depth of about 2 to 2.5 times the width of footing there is no need to putting the fiber reinforced soil throught this depth. sufficient for placing the fiber Only the depth equals to one fourth of size of footing is reinforced soil for increasing bearing capacity.
- The settlement decreases with increase in fiber content up to 0.50% after that decrease in settlement is very small. The settlement is minimum when the depth of fiber reinforcement is b/4. After that settlement decreases with increase in depth of fiber reinforced soil.

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