The Effect of Water Table Depth on Bearing Capacity of Randomly Distributed Waste Tyre Rubber Fibre Reinforced Clayey Soil

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Abstract. The bearing capacity (BC) of footing is considerably governed by soil settlement. In practice, the BC of soil can be improved by reinforcing the soil. The laboratory model tests were performed to investigate the effect of water table depth (WTD) on BC of reinforced soil. Randomly distributed shredded waste tyre rubber fibre (length-19mm, width-4.5mm) of 0.75% by dry weight of soil as reinforcement. The circular moulds (height-250mm, diameter-300mm) were used to prepare the test samples. A shallow depth, surface loading, smooth base mild steel circular footing (diameter (B)-75mm, height-60mm) was used in the study. The WTD maintained at different positions, where the ratio of depth of water table below the base (b) to the base width of the footing (B) are 0, 1, and 2 for both unreinforced and reinforced clayey soil. The samples were kept 96 hours for soaking. Tri-axial test loading frame was used to apply compressive load at a strain rate of 1.25 mm/min. The improvements in bearing capacity of reinforced soil over un-reinforced soil is 33% without water table effect and 28%, 23%, 20 % with water table effect at b/B ratios are 0, 1, 2, respectively. The WTD greatly decreases the BC. The BC of reinforced soil is greater than that of unreinforced soil for all b/B ratios.

Keywords: Bearing capacity ratio, Settlement ratio, Shredded tyre fibre, circular footing.

1 Introduction

The non-biodegradable tyre fibers can take long time to decompose completely and causes the environmental problems. The method of disposal by landfilling is not applicable due to the low density of the material causes the occupation of large volume. Every year millions of tyres were discarded, thrown away, or buried all over the world. Using waste tires in the form of shreds in Civil Engineering projects is a promising method of recycling this waste material [1]. In 2011, 7.8% of scrap tires were utilized in various Civil Engineering projects as reinforcement [2].

Reinforcement introduced to the soil or similar materials to improve engineering properties e.g. Strength, stiffness, permeability, compressibility, etc. [3]. Reinforcement is necessary in soils where chances of high erosion (soils with high sand and silt content) and the areas with soft soils (expansive soils) [4]. Soil erosion is due to physical movement of the soil particles caused by the wind, water, ice, animals, and human activities are required reinforcement [5]. Expansive soils, foundations damage to highways, bridges and buildings due to volume change are required improvement. Both cohesive and non-cohesive soils required reinforcement dealing with the different problems at a given site. The present study conducted on expansive soil with waste tyre rubber fibers as reinforcement elements. Kolay et.al., (2013) investigated the improvement in the bearing capacity of silty clay soil with thin sand layer on top and placing geogrids at different depths, concluded that the bearing capacity increases significantly with the increased number of geogrid layers [6]. Soil reinforced with optimum percentage of treated fibers at various H/B ratios of 0.2, 0.4, 0.6, 0.8, up to 2 [7]. The 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 [8]. In this paper, the effect of water table depth on bearing capacity of tyre fiber reinforced expansive soil were studied experimentally.

2 Materials

2.1 Clay

The present investigations have been made on the expansive (clayey) soil obtained from the deposits of “Vesu” area, Surat, Gujarat, India. The index properties of the soil were determined as per the IS test procedures [9-14]. The soil is classified as the high plasticity (CH) soil according to the IS Soil Classification [15]. The index properties of soil were presented in table 1.

Table 1. Physical and mechanical properties of soil.

Soil properties	Values
Specific gravity	2.56
Grain size analysis	
Gravel (%)	0
Sand (%)	10
Silt (%)	64
Clay (%)	26
Consistency limits	
Liquid limit (%)	64.45
Plastic limit (%)	30.66

Shrinkage limit (%)	10.41
Volumetric shrinkage limit (%)	57.98
Plasticity index	33.78
IS Classification	CH
Differential Free Swell Index (%)	70.35
Compaction study	
Optimum mixing moisture content (%)	23.39
Maximum dry unit weight (kN/m^3)	15
Unconfined compressive strength (kN/m^2)	114.25
Cohesion (kN/m^2)	57.12

2.2 Tyre fibers

The waste tire rubber fibers (WTRFs) were collected from "National Precured Retreaders" located at N.H. no 8 nearby Navsari. As the WTRFs had various lengths and diameters, it was not possible to define a specific aspect ratio. For the simplification it was divided into three groups using conventional sieve analysis procedure (retained on 4.75 mm IS sieve, passing through 4.75 mm IS sieve and retained on 2mm IS sieve & passing through 2mm IS sieve). The fibers retained on the 4.75 mm sieve size were used in the study. Type c fibers were shown in the figure 1.

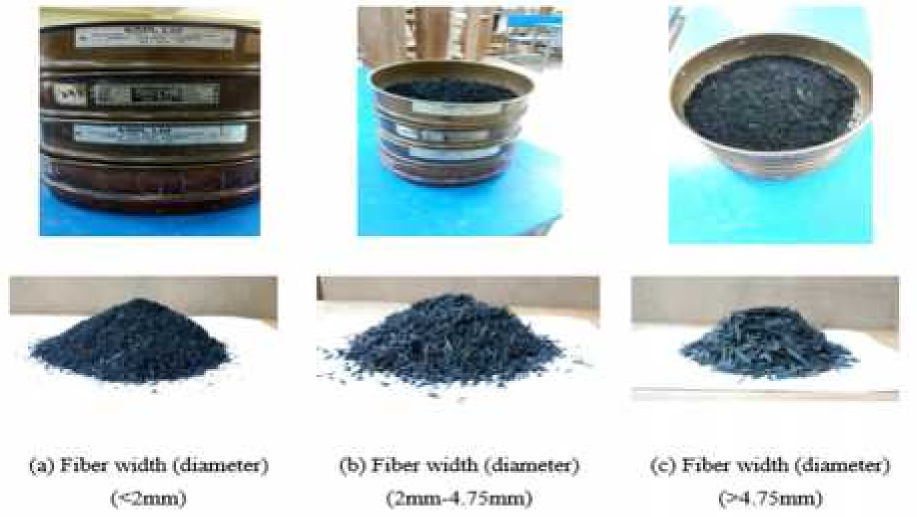

Fig. 1. Step by step procedure of seiving of fibers for the classification

3 Methodology

3.1 Test Moulds

The GI sheet of 1.21 mm (18 gauge) thickness was used in the study to prepare the moulds. The sheet was cut into three rectangular pieces of each sheet width is 300 mm, which is a height of mould and length is 880 mm, which is a perimeter of the mould. The sheets were drilled with a hole of 10 mm at a horizontal and vertical spacing of 20 mm and 30 mm centre to centre to allow the passage of water through holes into the soil sample. For the first, second, third, and fourth moulds, the holes are up to the height of 250 mm 170 mm, 50 mm, and 0 mm from the bottom. The holes were made up to different heights to maintain water table depth at different heights. Now, the rectangular sheet of each case rolled along the length direction and the ends were welded to make cylindrical mould. Proper care has been taken while making markings and welding. The cylindrical moulds diameter is 280 mm and height is 300 mm. Fig. 2. Shows the process of preparation of the moulds.

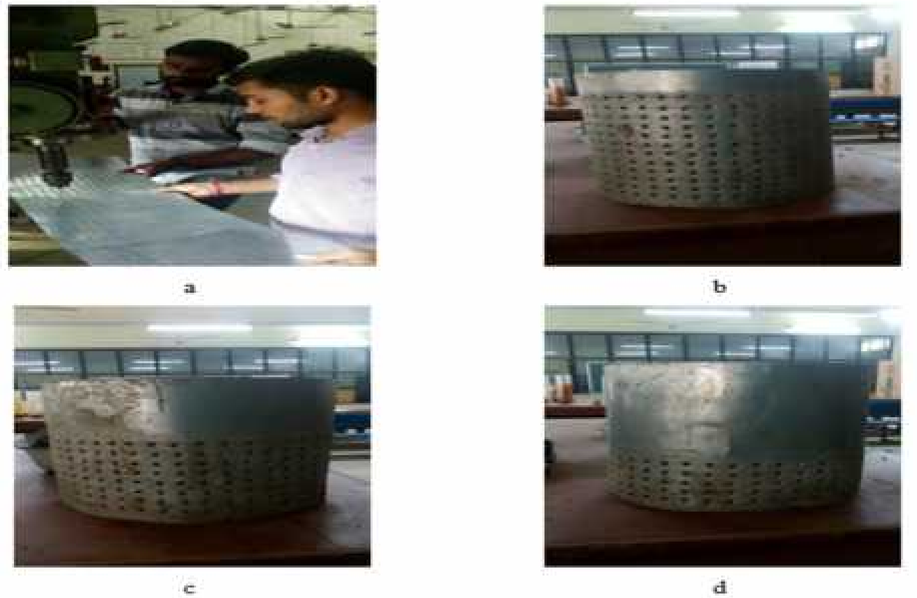

Fig. 2. (a) Placing of holes in both the directions, (b) b/D=0 mould, (c) b/D=1 mould, (d) b/D=2 mould

3.2 Test Footing

The circular footing was used in the study made up of steel with a diameter of 76.2 mm and height is 65 mm. Smooth surface footing condition is used in the study. Top surface of the footing is grooved about a diameter of 15 mm and depth is 5 mm to transfer load to the footing in a point load condition. Fig. 3 (a, b, & c) shows the physical model of the footing.

3.3 Base Plate

The base plate of 300 mm diameter and 10 mm thickness was prepared to place at the bottom of the sample during the test. Base plate is made up of steel as shown in the Fig. 3 (d).

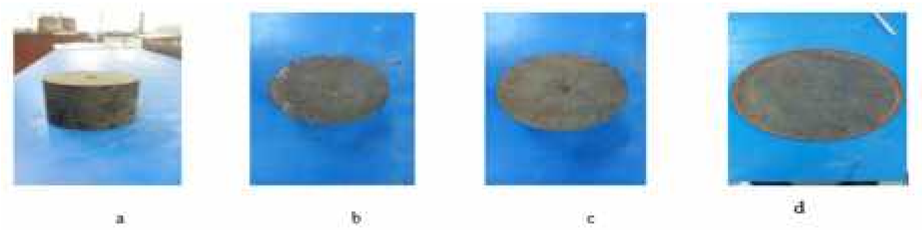

Fig. 3. Footing geometry (a) Circular steel footing (b) Smooth base footing, (c) grove at top to apply point load to the footing, (d) Base plate

4 Sample Preparation

The oven dried soil sample around 23 kg, optimum fibre content 0.75% and optimum mixing moisture content (OMMC) were used to prepare test samples. Total sample is prepared in three different trays of 7.6 kg oven dry soil in each tray. After the individual preparation, three trays soil sample poured in a single tray and mixed thoroughly to achieve uniform mixing. The prepared soil sample was left for 30 min to obtain uniform mix in terms of moisture equivalent. Soil was compacted in the mould with 2.65 kg hammer at a free fall height of 310 mm, placed by 3 layers and each layer having 103 blows. The process was depicted in fig. 4.

Fig. 4. Stages in the preparation of fibre reinforced soil (a) Weight of samples were taken to prepare FRS, (b) Fibres mixed with oven dry soil, (c) Adding water and thoroughly mixed, (d) Three parts combined to form uniform mix

Both the reinforced and unreinforced soil samples were prepared with the same procedure as described above. Un-soaked and soaked laboratory tests were performed at four conditions. Test-1 was performed on unsoaked in condition. Test-2, Test-3, and Test-4 are same as the test one except that the mould has holes at different depths of 250 mm, 170 mm, and 50 mm from bottom of the moulds respectively for 48 hours soaked condition.

5 Testing procedure

The tri-axial loading apparatus was used for applying the compressive load to the footing. The loading frame attached a load cell of capacity 5000 kg as shown in the Figure. The bottom of the load cell connected to a circular shank of size 50 mm to transfer load to the footing as point load. Small size of 10 mm diameter ball is used in between the load cell shank and footing to apply point load on to the footing. Fig. 6. shows the instrumentation of the sample for bearing test of the circular footing.

Fig. 5. Testig Apparatus and Instrumentation

Fig. 6. Testing procedure (a) Removing top cover after soaked for 96 hours, (b) Placing mould under loading frame along with footing at centre, (c) Applying point load to the footing, (d) Footing after testing, (e) Settlement of the footing, (f) Removing sample from the mould

Prepared sample is placed on the movable jack as shown in the Fig. 5. Linear variable differential transducer (LVDT) connected to base plate by placing bottom of the test sample. LVDT and load cell connected to the data acquisition system to record the load and settlement. All the tests were performed on the strain rate of 1.25 mm/min (gyre=2).

Fig. 6. (a) The sample is taken out from the water tank after the soaking period of 96 hours and kept 30 min at outside for removing of surface water. Fig. 6. (b) Places the circular footing at the center of the prepared test mould. Transfer the test mould along with footing to tri axial loading frame to the center to load cell. Fig. 6 (c) Place the circular ball between the footing and load cell shank to apply point load. The loads were calculated up to the maximum displacement of 30 mm. Failure load is taken as 7.5 mm displacement, which is the 10 % of the footing diameter. Fig. 6 (d) after loading, the sample was released from the load. The LVDT removed from the sample and kept out of the sample. Fig. 6. (e) footing is removed from the test mould and observes the settlement behavior of the footing. Settlement of the footing is uniform throughout the 30 mm depth as shown in the Figure. Fig. 6. (f) the sample is taken out and removed from the mould. Sample is not reusable.

The water table effect was simulated by varying the height of holes of 10 mm diameter at horizontal and vertical center to center spacing of 20mm X 30 mm on the mould to allow the passage of water through holes into the soil sample [fig.2]. The water level in the soaking tank was up to the height of holes to maintain water table depth from b/B=0 to b/B=2 [fig.2]. The effect of capillary rise above the water table depth was neglected. All tests were performed on Unconsolidated Undrained (UU) conditions at a strain rate of 1.25 mm/min.

6 Results and Discussions

6.1 Effects of Water Table Depth on Bearing Capacity of Fiber Reinforced Soil

The presence of water in the soil causes the reduction in shear strength of the soil. Moisture content between the soil grains acts as the lubrication finally causes the reduction in strength. Problematic soils should be protected from the entrance or presence of moisture. The water table greatly changes the moisture content in the soil. Bearing capacity of soil greatly depends on the depth of water table from the ground level.

Four model tests were performed to find out the bearing capacity of randomly distributed waste tire rubber fiber reinforced clayey soil with the presence of water table at different b/B ratios and without water table effect.

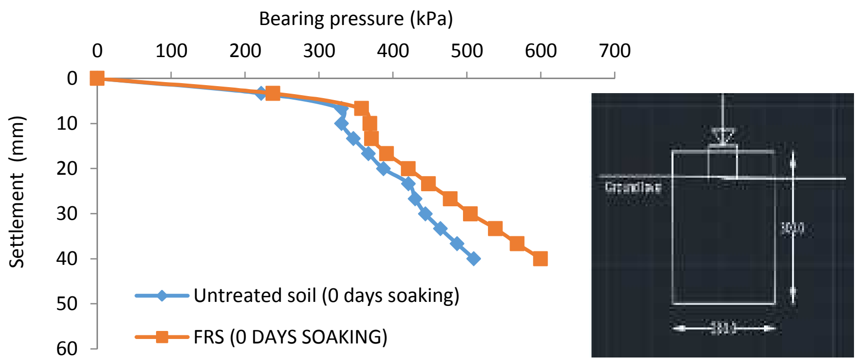

Fig. 7. Bearing pressure vs Settlement curve for FRS and Untreated soil without water table

Fig. 7. Represents the bearing capacity of untreated and FRS without water table effect. The bearing capacity at 10 % settlement ratio is 280 kPa and 380 kPa for untreated and FRS soil. Improvement in bearing capacity is 100 kPa, which is 35.71 % over untreated soil. Considerable improvement is achieved with the inclusion of tire fiber at optimum fiber content of 0.75 %.

The tire fibers elements acts as a tensile elements in the soil mass to enhance it natural stability and strength. The reinforcing elements bringing in contact with the surface of aggregate of soil mass. When load applied on soil mass cause's pressure and a strain on the tire fiber, it creates a tensile load which resist soil movement and provide additional support for increased strength. This way, a tire fiber reinforced soil system is created which provides greater shear strength than the soil mass alone [4]

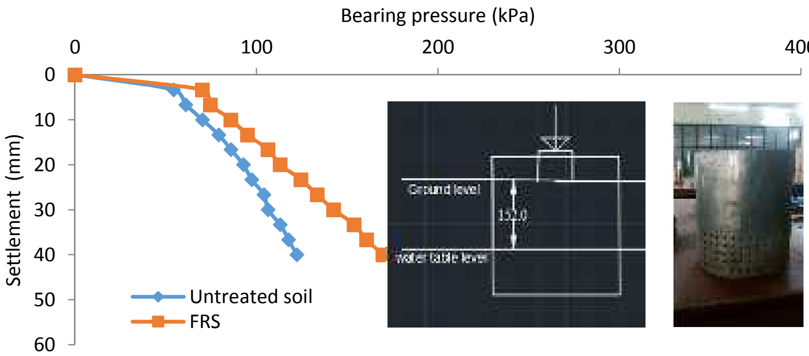

Fig. 8. Bearing pressure vs Settlement curve for FRS and Untreated soil with water table effect at b/B=2

Fig. 8. Shows the bearing capacities at 10 % settlement ratio are 70 kPa and 90 kPa for untreated and FRS soils. The reduction in bearing capacity, when compared with the untreated and FRS soils without water table effects are 75 % and 76.31 %. The percentage reduction in bearing capacity is more in FRS compared with untreated soil. With the presence of water table, the bearing capacity greatly reduced.

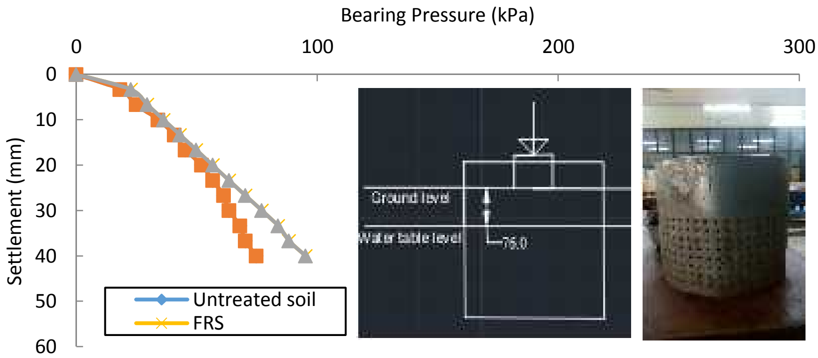

Fig. 9. Bearing pressure vs Settlement curve for FRS and Untreated soil with water table effect at b/B=1

Fig. 9. Represents the b/B=1. The bearing capacities at b/B=1 are 35 kPa and 43 kPa as shown in the Fig. at 10 % settlement ratio. The reduction in bearing capacities are 87.5 % and 88.68 % for untreated and FRS soils, respectively. Percentage reduction in bearing capacity is more in FRS, when compared with untreated soil.

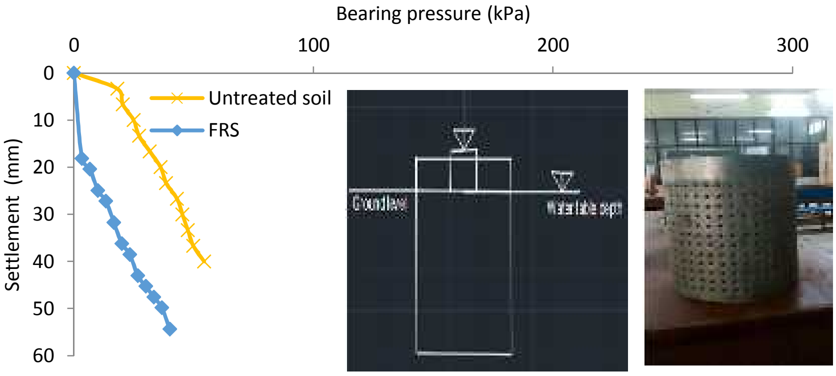

Fig. 10. Bearing pressure vs Settlement curve for FRS and Untreated soil with water table effect at b/B=0

Fig. 10. Represents the b/B =0. The water table depth is at the base of the footing. Lesser the water table depth from the ground surface, greater the reduction in bearing capacity. The bearing capacities are 25 kPa and 3 kPa for untreated and FRS soils at 10 % settlement ratio. Percentage reduction in bearing capacities are 91.0 % and 99.21 % for untreated and FRS soils, respectively when compared with the absent of water table effect on both the cases.

From the figure 7, 8, 9 and 10, the bearing capacity of fiber reinforced soil is higher than the untreated soils except in the case of the when the water table depth at a ground surface. The bearing capacity of FRS is less than the untreated soil, when the water table depth at the top of the ground surface. In the above case, the water acts as a lubricant between the fibers and soil particles, causes the shear sliding of tyre fibers over the soil sample.

7 Conclusions

The improvements in bearing capacity of reinforced soil are 33%, 23% and 20 % over unreinforced soil at without water table effect and with water table effect at b/B are 1, and 2, respectively. The bearing capacity of untreated soil is more than the FRS, when the water table depth at the top of the ground surface. Percentage reduction in bearing capacity is more in soaked FRS, when compared with soaked untreated soil. Fibers are not applicable for the modification of clayey soil, when the soil touches the moisture due to change in water table depth. Tire fibers can be successfully used for the modification of clayey soils, where the effect of water table is absent.

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