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Performance of Coir fiber Reinforced Clayey Soil

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Abstract

The Soil reinforcement is an effective and reliable technique for improving strength and stability of soils. Several studies have been conducted to investigate the influence of randomly oriented discrete inclusions (fibers, mesh elements, waste material e.g. plastic strips, tire chips, etc.) on the highly compressible clayey soils. Coir is a natural biodegradable material abundantly available in some parts of south and coastal regions of India. Most of these studies were conducted on small size samples in triaxial, C.B.R., unconfined compression and direct shear tests. The present work focused on effect of coir on bearing capacity and settlement of footing with parameters such as thickness of reinforced layer (B, B/2, B/4) with 0.25%, 0.5%, 0.75% & 1.0% of coir using the laboratory model tests on square footings supported on highly compressible clayey soil reinforced with randomly distributed coir fiber. Provision of coir reinforced layer increases bearing capacity ratio up to 1.5 to 2.66. There is significant increase in bearing capacity of clayey soil with the inclusion coir fibers. At 25 mm depth of fiber reinforced soil (B/4) and 0.50% fiber content the SBC is maximum. There is no need to place the fiber reinforced soil throughout the depth as the soil is affected to a significant depth of 2 to 2.5 times the width of footing. Only one fourth width of footing (B/4) is sufficient for increasing the SBC. In general, the results shows that the provision of coir reinforced layer, reduces the settlement and improves the bearing capacity , which found to be economical techniques among various types of bearing capacity improvement techniques.

***Keywords** - Fiber reinforced clayey soil, model footing test, ultimate bearing capacity.*

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I. INTRODUCTION

The less amount of land is available for construction because of increasing the urbanization and modernizations. Everywhere land is being utilized for various structures from an ordinary house to sky scrapers, from bridges to airports and from village road to highways or expressway. Owing to this, construction of structures these days is being carried on land having weak or soft soil. Now, stability of any structure depends on the properties of soil. Using land having soft soil for construction leads to various ground improvement techniques such as soil stabilization and soil reinforcement. Most of the soil available are such that they have good compressive strength adequate shear strength but weak in tension/ poor tensile strength. To overcome the same, many researchers have concentrated their studies on the development of new such materials, through the elaboration of composites.

In the case of geotechnical engineering the idea of inserting fibrous materials in a soil mass in order to improve its mechanical behavior has become very popular. The concept of earth reinforcement is an ancient technique and demonstrated abundantly in nature by animals, birds and the action of tree roots. These reinforcements resists tensile stress developed within the soil mass thereby restricting shear failure. Reinforcement interacts with the soil through friction and adhesion. The practicing engineers are employing this technique for stabilization of thin soil layers, repairing failed slopes, soil strengthen around the footings and earth retaining structures. The inclusion of randomly distributed discrete fiber increases strength parameters of the soil as in case of reinforced concrete construction.

II. MATERIAL USED FOR INVESTIGATION

For the present study soil samples of blackish colour classified as CH according to Soil Classification System were used. The Engineering properties of soil are listed in Table 1.

TABLE.1: Engineering properties of soil used

Sl. No.	Properties	Value
1	Specific Gravity	2.16
2	Grain Size Analysis Gravel% - Sand% - Silt & Clay% -	 1.6% 18.4% 80.0%
3	Consistency limit LL - PL - PI -	 62.5% 22.19% 40.31%
4	IS Classification	CH

Coir fibers are used in this investigation as a reinforcement of size 20-30 mm. The specifications and photograph of the coir fibers are given in Table 2 and Fig.1.

TABLE.2: Physical and engineering properties of coir

Sl. No.	Properties	Value
1	Specific Gravity	0.71
2	Cut Length	20-30mm
3	Diameter	0.20-0.25mm
4	Colour	Brown

Figure.1. Coir fibers used for reinforcement in clayey soil

III. MODEL FOOTING TEST

Model footing tests on the fiber reinforced soil were conducted to investigate the pressure settlement behavior of randomly distributed fiber reinforced soil and effect of fiber content on the bearing capacity of the randomly distributed fiber reinforced soil. All the tests were conduct on the square footing of size 100 mm in square tank of size 500 mm x 500 mm x 400 mm (deep). Model footing is made of cast iron to have perfect rigidity and machined to proper dimensions. The loading arrangement is as shown in Fig.2. The base of the footing is made rough on contact face by pasting emery paper of extra fine grade, to simulate the roughness of actual footings.

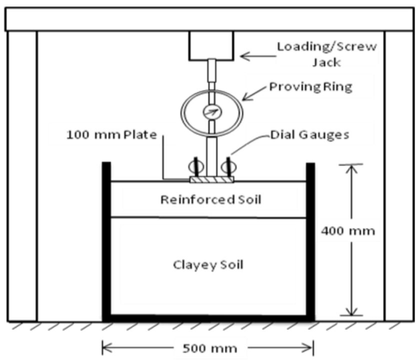

Figure.2. Loading arrangement of model footing test

The tank is made of sufficient thickness to withstand lateral expansion under loads. The dimensions of tank are kept more than five times the width of footing tested so that it should not include boundary effects. The parameters used in this test are percentage of fiber reinforcement and depth of placement of fiber reinforced clay as listed in the Table 3, where B is the width of the model footing tested.

TABLE.3: Parameters of test program

Size of Footing	100 mm X 100 mm
Percentage of Coir fiber Reinforcement	0.25%, 0.50%, 0.75% & 1.0% (By Weight)
Depth of Fiber Reinforced Soil	B/4 = 25mm, B/2 = 50 mm, B = 100 mm

For achieving uniformity, the density and moisture content of unreinforced and fiber reinforced soil were kept constant throughout the test program, thought MDD and OMC are different for unreinforced and fiber reinforced soil. Coir fibers were mixed manually in clay, till the fiber gets mixed homogeneously with clay. The inside of the tank is mark at every five cm. The unreinforced and then the fiber reinforced clay was place in tank in layers of 50mm thickness and each layer was compacted to attain the required density and height. Each layer is properly compacted with tamper having circular base of 150 mm diameter to give required density. After filling the tank, the top surface of clay is leveled.

The footing was placed in the middle of the tank and after removing 50mm top layer for achieving proper compaction. The level of the footing was checked by sprit level to avoid eccentric loading. The footing was placed over a fine sand layer of thickness 3mm and the center of the plate is coincide with the center of reaction beam, with the help of plumb bob. A ball and socket arrangement is inserted on the footing to keep the direction of the load vertical throughout the test. The proving ring of 50 kN capacity was placed over socket for measuring the load. The loading jack was placed over the proving ring with the loading column in between the jack and reaction beam so as to transfer the load to the plate. The settlement was measured by two dial gauges, each on either side of footing, resting on two magnetic bases.

A seating load of 7 kN/m2 was applied and released after 30 minutes before starting the test. The load was applied and increased an increment of about one tenth of the estimated ultimate load. The settlement was observed for each increment of load after an interval of 1, 2.25, 4, 6.25, 9, 16, and 25min and thereafter hourly intervals to the nearest 0.01 mm. The load increment was applied when the rate of settlement reduced to 0.01 mm per hour. A load settlement curves were plotted out for unreinforced as well for fiber reinforced soils. The settlement was plotted as abscissa against corresponding load intensities as ordinate for well defined failure point, both to logarithmic scale. From curves the ultimate bearing capacity (UBC) for unreinforced and fiber reinforced soils were calculated.

IV. RESULTS AND DISCUSSION

4.1 Standard Proctor Compaction Tests

Standard proctor's compaction tests using light compaction have been carried out in accordance with relevant IS standard, to determine the maximum dry density (MDD) and optimum moisture content (OMC) for the selected soil. The maximum dry density and optimum moisture content for unreinforced soil is 17.28 kN/m^3 and 18.1% respectively as shown in Fig.3.

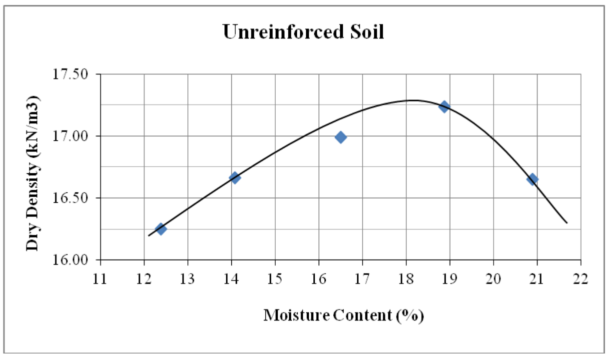

Figure.3: Maximum Dry Density for Unreinforced Soil

And the maximum dry density and optimum moisture content for reinforced soil with 0.25% coir fiber is 16.9 kN/m^3 and 19.17% respectively as shown in Fig.4.

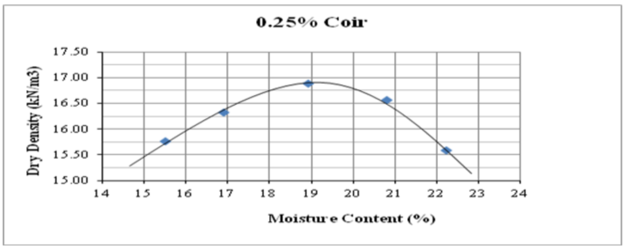

Figure.4: Maximum Dry Density for Reinforced Soil with 0.25% Coir

And the maximum dry density and optimum moisture content for reinforced soil with 0.5% coir fiber is 16.7 kN/m^3 and 20.23% respectively as shown in Fig.5.

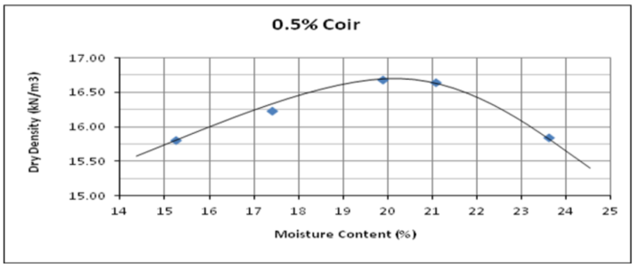

Figure.5: Maximum Dry Density for Reinforced Soil with 0.5% Coir

And the maximum dry density and optimum moisture content for reinforced soil with 0.75% coir fiber is 16.65 kN/m^3 and 20.53% respectively as shown in Fig.6.

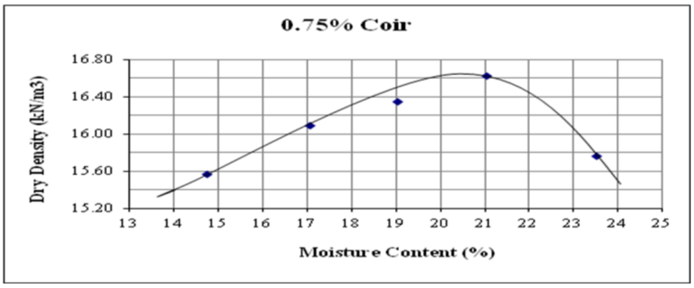

Figure.6: Maximum Dry Density for Reinforced Soil with 0.75% Coir

Whereas the maximum dry density and optimum moisture content for reinforced soil with 1.0% coir fiber is 16.62 kN/m^3 and 20.76% respectively as shown in Fig.7.

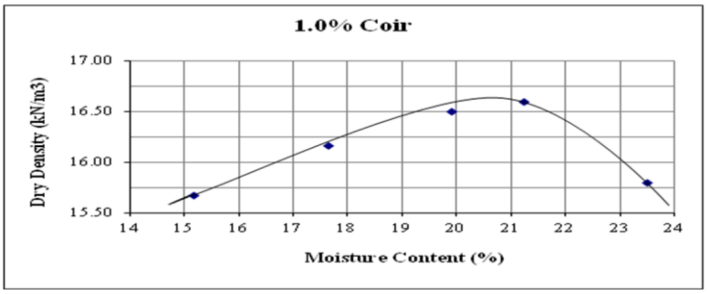

Figure.7: Maximum Dry Density for Reinforced Soil with 1.0% Coir

4.2 Model Footing Tests

Total thirteen model footing tests have been carried out in accordance with relevant IS standard for unreinforced soil and reinforced soil with 0.25%, 0.5%, 0.75% and 1.0% coir fiber for 100mm, 50mm and 25mm thickness. The load settlement curve for unreinforced soil is as shown in Fig.8.The load settlement curves for reinforced soil with 0.25% coir for 100mm, 50mm and 25mm thickness are as shown in Fig.9, Fig.10 and Fig.11 respectively. The load settlement curves for reinforced soil with 0.5% coir for 100mm, 50mm and 25mm thickness are as shown in Fig.12, Fig.13 and Fig.14 respectively. And the load settlement curves for reinforced soil with 0.75% coir for 100mm, 50mm and 25mm thickness are as shown in Fig.15, Fig.16 and Fig.17 respectively. Similarly the load settlement curves for reinforced soil with 0.25% coir for 100mm, 50mm and 25mm thickness are as shown in Fig.18, Fig.19 and Fig.20 respectively. Fig.21 to Fig.24 shows combination of the load settlement curves with 0.25%, 0.5%, 0.75% & 1.0% coir for different depths of reinforced layer. The load settlement curve for fiber reinforced soil, when depth of fiber reinforced soil is kept 25mm (B/4) is above than that of the 50mm (B/2), 100mm (B) and unreinforced soil in all four figures.The ultimate bearing capacity (UBC) for reinforced soil having depth of reinforcement is equal to depth B/4 (25mm) is observed always maximum for all the fiber content (0.25%, 0.5%, 0.75% & 1.0%) as shown in Fig.21 to Fig.24.

Fig.8 represents the load settlement curve for unreinforced soil. From figure ultimate bearing capacity for unreinforced soil is found to be 250.0 kN/m2. Similarly ultimate bearing capacity for reinforced soil with 0.25% coir for 100 mm, 50 mm and 25 mm depth is found to be 360.00 kN/m2, 415.00 kN/m2, 570.00 kN/m2 respectively. The ultimate bearing capacity for reinforced soil with 0.5% coir for 100 mm, 50 mm and 25 mm depth is found to be 425.00 kN/m2, 495.00 kN/m2, 665.00 kN/m2 respectively. The ultimate bearing capacity for reinforced soil with 0.75% coir for 100 mm, 50 mm and 25 mm depth is found to be 375.00 kN/m2, 445.00 kN/m2, 590.00 kN/m2 respectively. And the ultimate bearing capacity for reinforced soil with 1.0% coir for 100 mm, 50 mm and 25 mm depth is found to be 320.00 kN/m2, 360.00 kN/m2, 525.00 kN/m2 respectively. The UBC for reinforced soils are presented in Table 4.

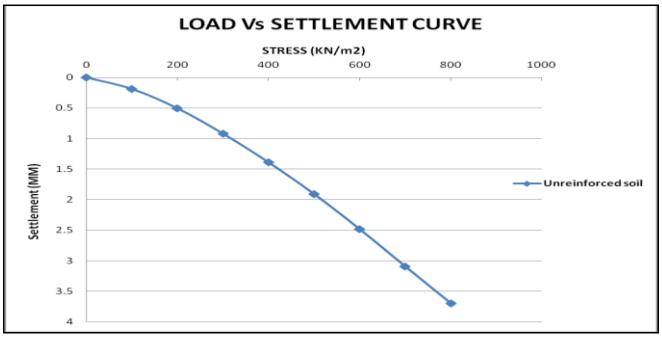

Figure.8: Load Settlement Curve for Unreinforced Soil

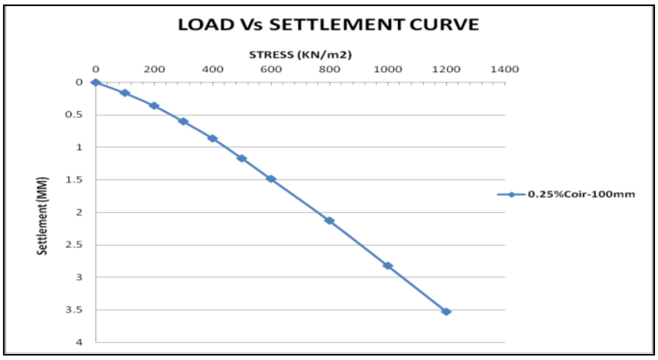

Figure.9: Load Settlement Curve for Reinforced Soil with 0.25%
Coir- 100mm Depth

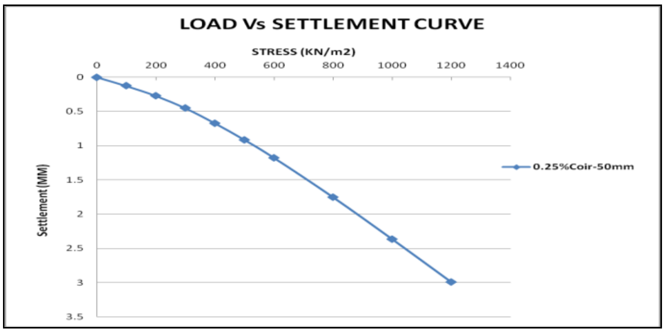

Figure.10: Load Settlement Curve for Reinforced Soil with 0.25% Coir- 50mm Depth

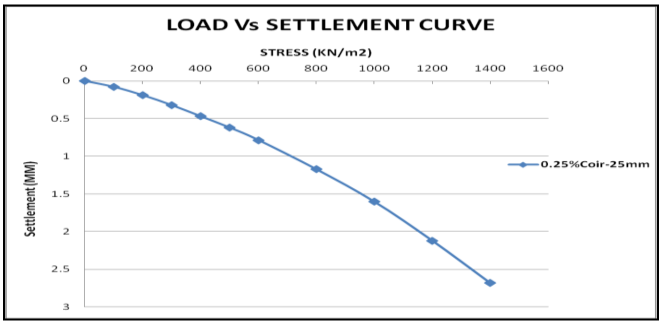

Figure.11: Load Settlement Curve for Reinforced Soil with 0.25% Coir- 25mm Depth

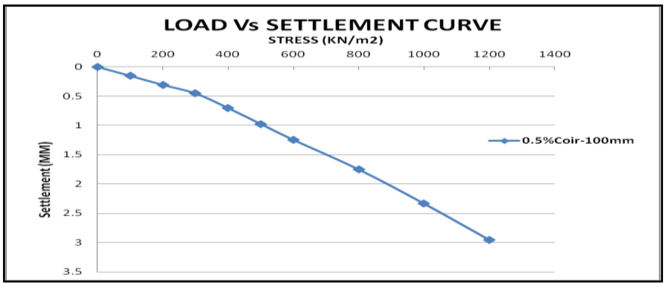

Figure.12: Load Settlement Curve for Reinforced Soil with 0.5% Coir- 100mm Depth

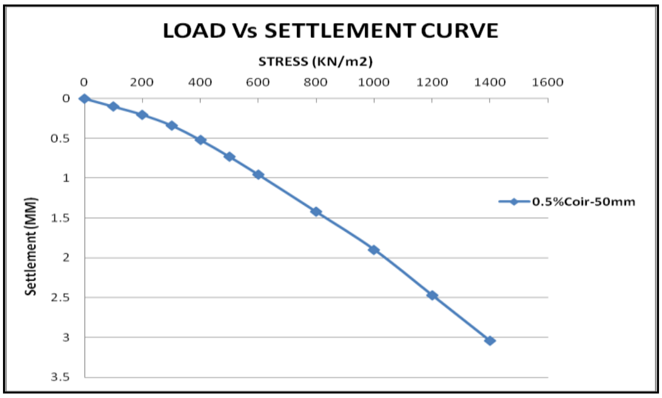

Figure.13: Load Settlement Curve for Reinforced Soil with 0.5% Coir- 50mm Depth

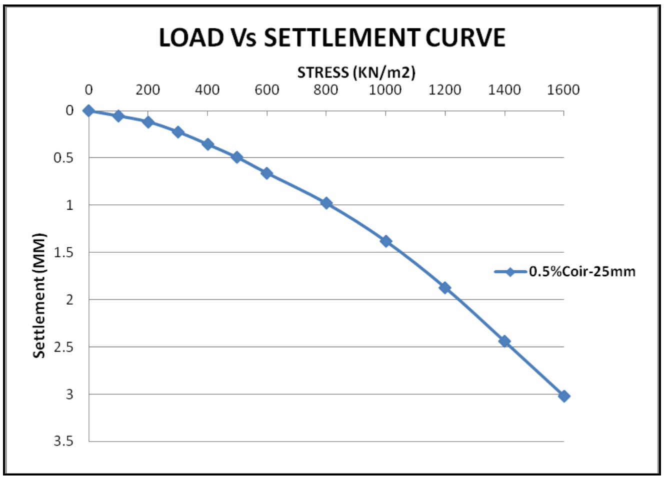

Figure.14: Load Settlement Curve for Reinforced Soil with 0.5% Coir- 25mm Depth

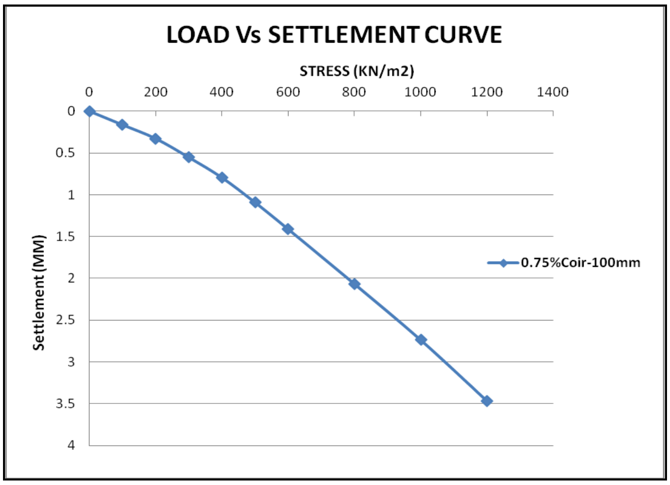

Figure.15: Load Settlement Curve for Reinforced Soil with 0.75% Coir- 100mm Depth

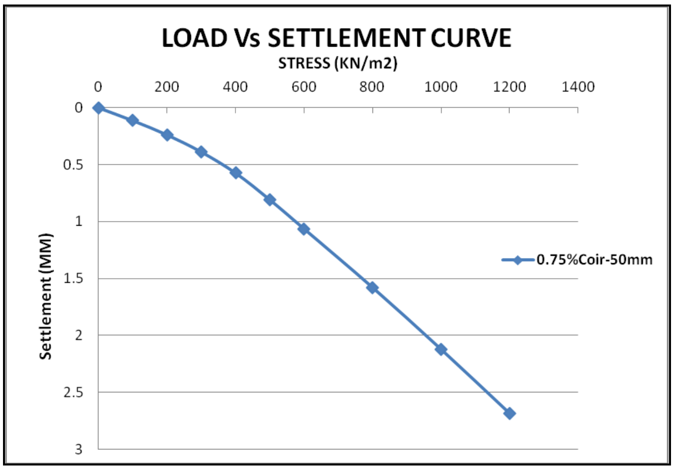

Figure.16: Load Settlement Curve for Reinforced Soil with 0.75% Coir- 50mm Depth

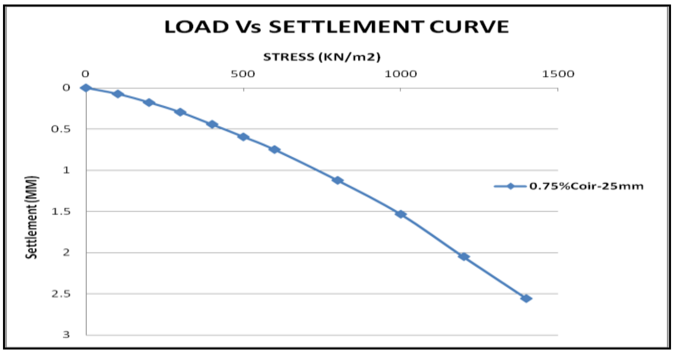

Figure.17: Load Settlement Curve for Reinforced Soil with 0.75% Coir- 25mm Depth

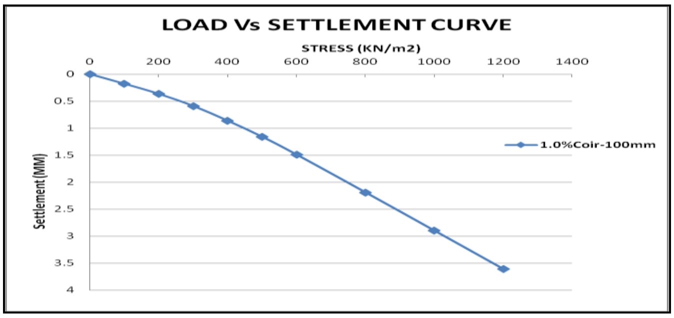

Figure.18: Load Settlement Curve for Reinforced Soil with 1.0% Coir- 100mm Depth

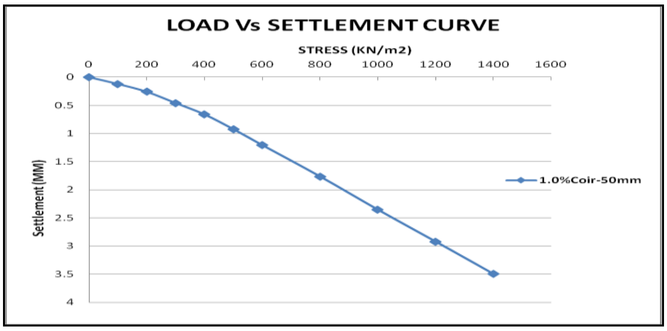

Figure.19: Load Settlement Curve for Reinforced Soil with 1.0% Coir- 50mm Depth

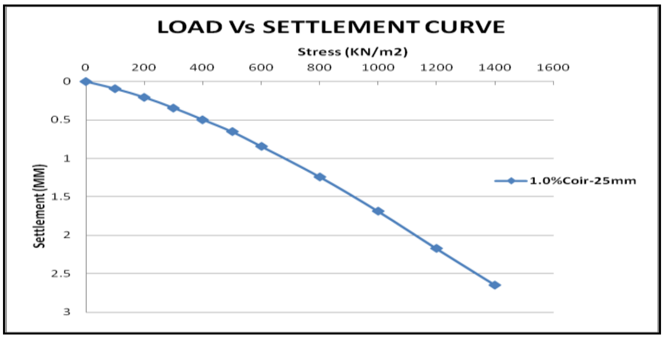

Figure.20: Load Settlement Curve for Reinforced Soil with 1.0% Coir- 25mm Depth

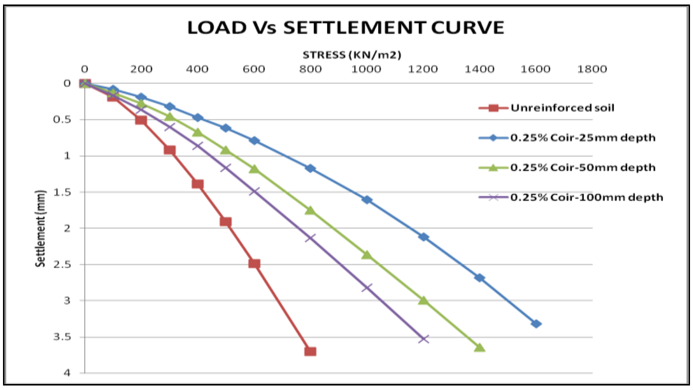

Figure.21: Load Settlement Curve for Fiber Reinforced Soil with 0.25% Coir- 25, 50 and 100mm Depth

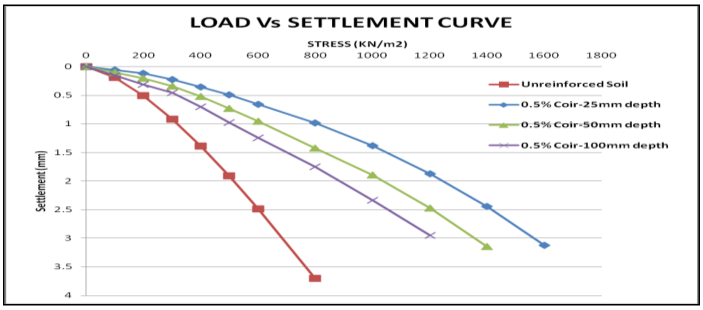

Figure.22: Load Settlement Curve for Fiber Reinforced Soil with 0.5% Coir- 25, 50 and 100mm Depth

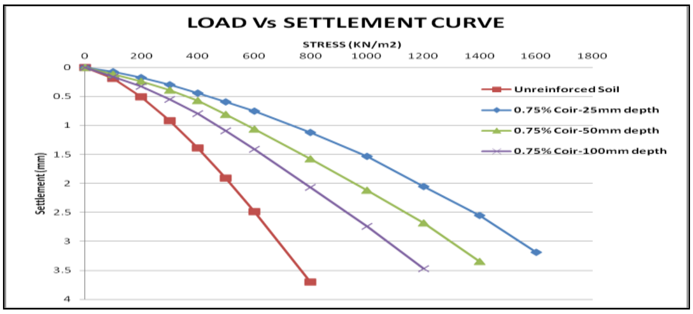

Figure.23: Load Settlement Curve for Fiber Reinforced Soil with 0.75% Coir- 25, 50 and 100mm Depth

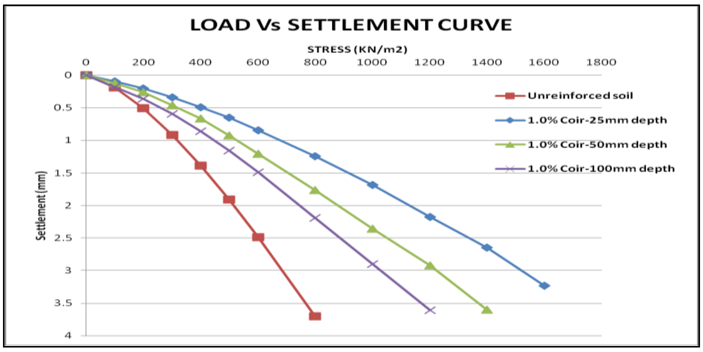

Figure.24: Load Settlement Curve for Fiber Reinforced Soil with 1.0% Coir- 25, 50 and 100mm Depth

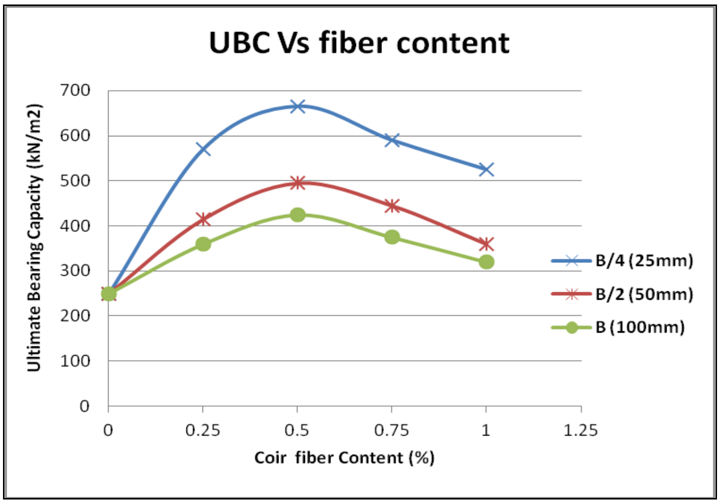

Figure.25: Ultimate Bearing Capacity (kN/m2) Vs Coir Fiber Content for Various Depth of Reinforced Layer

Table 4: Summary of Ultimate Bearing Capacity

Fiber Content (%)	**Ultimate Bearing Capacity (kN/m2)**		
	Depth of fiber		
	B (100mm)	B/2 (50mm)	B/4 (25mm)
0.25	360	415	570
0.50	425	495	665
0.75	375	445	590
1.0	320	360	525

The load settlement curves for coir fiber reinforced soils with various combinations and compare with unreinforced soil are shown from Fig.25. The load settlement curve for fiber reinforced soil, when depth of fiber reinforced soil is kept 25mm (B/4) is above than that of the unreinforced clay and when the depth is kept 50mm (B/2) and 100mm (B) as shown in Fig.25. Thus UBC has maximum at 25mm (B/4) depth of fiber reinforced soil with fiber content of 0.5%.The ultimate bearing capacity for reinforced soils is presented in Table.4. The bearing capacity ratio (BCR) is the ratio of ultimate bearing capacity of reinforced soil to the ultimate bearing capacity of unreinforced soil. The maximum bearing capacity ratio gives us the optimum percentage of coir fibers and the optimum depth of reinforcement. The bearing capacity ratios for various reinforcement and depths are presented in Table.5.

Table 5: Summary of Bearing Capacity Ratio

Fiber Content (%)	**Bearing Capacity Ratio**		
	Depth of fiber		
	B (100mm)	B/2 (50mm)	B/4 (25mm)
0.25	1.44	1.66	2.28
0.50	1.70	1.98	2.66
0.75	1.50	1.78	2.36
1.0	1.28	1.44	2.10

V. CONCLUSION

The results have been concluding from model footing test. There is significant increase in bearing capacity of clayey soil with the inclusion coir fibers. The ultimate bearing capacity is found to be 250.0 kN/m2 for unreinforced soil. The ultimate bearing capacity for reinforced soil with 0.25% coir fiber for 100mm, 50mm and 25 mm depth is found to be 360.0 kN/m2, 415.0 kN/m2, 570.0 kN/m2 respectively. The ultimate bearing capacity for reinforced soil with 0.5% coir fiber for 100 mm, 50 mm and 25 mm depth is found to be 425.0 kN/m2, 495.0 kN/m2, 665.0 kN/m2 respectively. Similarly ultimate bearing capacity for reinforced soil with 0.75% coir fiber for 100 mm, 50 mm and 25 mm depth is found to be 375.0 kN/m2, 445.0 kN/m2, 590.0 kN/m2 respectively. And the ultimate bearing capacity for reinforced soil with 1.0% coir fiber for 100 mm, 50 mm and 25 mm depth is found to be 320.0 kN/m2, 360.0 kN/m2, 525.0 kN/m2 respectively.

The ultimate bearing capacity (UBC) is increase with increase in fiber content up to 0.50% and then it decrease with further inclusion of fibers. And the UBC is observing more for depth of B/4 for all the percentage of coir fiber reinforcement.`The ultimate bearing capacity (UBC) is maximum at 0.50% fiber content having 25 mm depth of fiber reinforced soil (B/4). Thus though the soil is affected to a significant depth of 2 to 2.5 times the width of footing, there is no need to putting the fiber reinforced soil throughout this depth. Only one fourth of width of footing (B/4) is sufficient for increasing the UBC.

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