Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 6, Issue 4; April-June, 2019, pp. 232-236

http://www.krishisanskriti.org/Publication.html

Strength and Stiffness behaviour of the Black Cotton Soil Reinforced with Tire Chips under Ring Footing

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Abstract—*Expansive soil or swelling soils are one of the problematic soils. Swelling and shrinkage behaviour of the soil with variation of the water content causes different problems in the structures. Settlement of the structure, cracking in the different components of the structures etc. are some major problems caused in the structure constructed over such soil. In India Black cotton soil is one of the expansive or swelling soils. For constructing the structures over black cotton soil, different techniques are developed. Utilization of the admixtures and reinforcement are most popular technique. In this study series of the model test over the ring footing supported by black cotton soil mixed with the tire chips are performed to understand the strength and stiffness behaviour of soil mixed with tire chips. Impact of the tire content and depth of the tire chips reinforced soil on the load carrying capacity of the black cotton soil is investigated. Tire chips content varied in this study was 5-20%. While, depth of the footing were varied from 0.5D to 1.5 D, where D is the diameter of the ring. Results obtained from the model tests have shown that the maximum performance occurred at the 10% tire content and at the depth of 0.5 D.*

Keywords: *Ring footing, Expansive soils, Stiffness, Tire-chips.*

1. INTRODUCTION

With growing population need of heavy structures like high rise buildings, towers, chimney etc. is increasing. For stability of such heavy structures different researchers have worked to find out innovative and economical solutions. Ring footing is one of the foundation types suitable for the structures like: chimney, bridge piers, tower, water storage tank etc. In ring footing material requirement is lesser than the circular footing. So it is economical than the circular footing [1]. . Different studies have shown that the performance of the ring footing depends upon the ratio of the inner to outer radius. Studies have also shown that the ring footing perform optimum when the range of ratio of inner to outer radius exist from 0.2 to 0.4. Many works are done to understand the behavior of the ring footing over different soil condition [2-6]. Swelling soil like, Black cotton soil is problematic in nature which causes swelling and shrinkage behavior with variation of the water content. In such soil, problems of geotechnical engineer increases. Black cotton soil has relatively lower subgrade modulus. The moisture change that generates volume change beneath the structure occurs in unsaturated soils located above the ground water table. The behaviour of unsaturated soils is often not fully analyzed for residential construction where there is a tendency to use more empirically based solutions. With the advancement in ground improvement techniques utilization of waste materials increases and problem of dumping has been resolved partially.

To improve the strength related behavior of the soil different ground improvement techniques are available. Utilization of the admixture for the improvement of the black cotton soil is one the popular ground improvement techniques. Fly ash, pond ash, lime, tire chips etc are some popular used admixtures. Different studied have shown that these materials have potential to improve the behavior of the soil significantly [7-11]. Tire chips are obtained from the scrap tire. Huge amount of scrap tire produced every year. Dumping of scrap tire creates huge environmental problems due to bulk production. Reutilization of these scrap tires form different purposes is important for the management of waste tires. In geotechnical application these waste tires can be utilized in bulk. Different works is done for the utilization of these wastes in geotechnical application [12-18]. The performance of the tire reinforced soil under ring footing is not yet well understood. In this study the behavior of the black cotton soil mixed with the tire chips is investigated under ring footing.

2. MATERIAL USED

Black Cotton soil

Black Cotton Soil is used for the study and it has been collected from Nagpur city. The soil was collected from an open field by method of disturbed sampling at a depth of 1 meter below the natural ground surface. The soil was dried and passed through IS sieve 4.75 mm before being used in this investigation. This soil is rich in Montmorillonite and responsible for swelling-shrinkage behaviour. Physical and Chemical properties of the black cotton soil is presented in the Table 1 and 2. From the particle size analysis it was found that the 80% of the soil particles were fine grained. 50% soil particles were in the range of the clay size.

Table 1 Physical properties of soil

Properties	Values	Unit
coefficient of uniformity (C_u)	28.89	-
coefficient of curvature (C_c)	2.13	-
moisture content (OMC)	23	%
Specific Gravity	2.1	-
Liquid Limit	62	%
Plastic Limit	35	%
effective particle size, D_{10}	0.22	mm
maximum dry unit weight, γ_{max}	17.4	kN/m^3
minimum dry unit weight, γ_{min}	14.3	kN/m^3

Table 2 Chemical Properties of Soil

Constituents	Values (%)
Silica (SiO_2)	52.85
Alumina (Al_2O_3)	12.24
Ferric (Fe_2O_3)	8.04
Calcium (CaO)	6.01
Magnesium (MgO)	2.94
Titanium (TiO_2)	0.24
Potassium (K_2O)	0.48
Sodium (Na_2O)	0.26

Tire chips

Tire chips used in experiment was manually cut to width 0.4 cm and length 2 cm. The Shreds were cut from tires with the help of scissors as shown in Fig. 1. The cut chips were then sieved through standard sieves of 12.5 and 4.75 mm. The chips passing 12.5 and retained on 4.75 mm were used in the study. For commercial usage cutting machines can be employed to expedite the process and more improved chippings. The Waste Tire collected from Transport Nagar Gorakhpur.

Fig. 1 Tire Chips

Table 3 Properties of tire chiips

Properties	Values	Units
Specific gravity	1.01	-
D_{60}	0.92	mm
D_{50}	0.73	mm
D_{30}	0.52	mm
D_{10}	0.26	-
Coefficient of uniformity (C_u)	3.54	-
Coefficient of curvature (C_c)	1.13	-

3. DETAILS OF THE EXPERIMENTAL PROGRAM

A series of model tests were performed on ring footing supported on unreinforced and reinforced soil in this study. The schematic diagram of the experimental setup is shown in Fig. 3. Model test was performed in steel tank of size 1 m x 1 m x 1m. The sides and bottom of the tank were made up of 9 mm thick steel sheet, welded to the base framework of steel angles and plates. The vertical load was applied to model footing with the help of hydraulic jack of 250 kN capacity. Size of the model ring used in this was of 200 mm external diameter and 50 mm internal diameter.

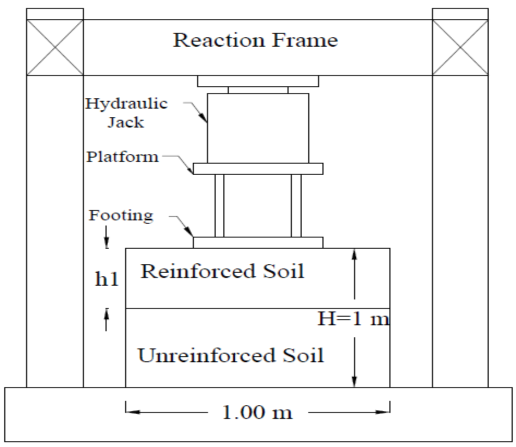

Fig. 3 Details of test assembly

Tire chips were used as admixture, which was mixed with soil and placed below the foundation. Fig. 4 shows the schematic diagram of the reinforcement layer. Content of tire and depth of the mix of tire chips and soil is varied and their impact is investigated. u/D ratio varied in this study was 0.5, 1, 1.5. Where, 'u' is the depth of the soil mixed with the tire chips. D is diameter of the ring footing. Content of the tire chips varied from 5-20%.

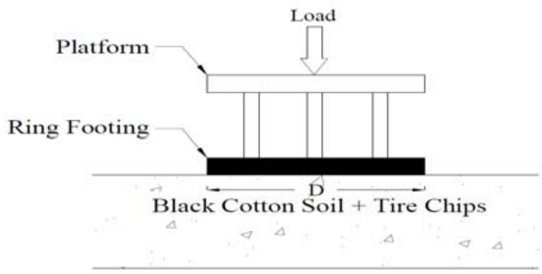

Fig. 4: Schematic diagram of the foundation bed mixed with the tire chips

Soil bed for the study was prepared in similar way as suggested by verma et al. [19]. For understanding the resultant settlement under reinforced soil bed, series of different laboratory tests i.e., plate load tests were conducted to evaluate the effect of reinforcement on bearing capacity and settlement of ring footing under static loads. The footing was centred in the tank, with the length of the footing parallel to the width of the tank. The footing was loaded by a hydraulic jack supported against a reaction frame. The load was applied incrementally and each load increment was maintained constant until the footing settlement stabilized and there was no significant change in settlement (i.e., 0.02 mm/min). The load applied to the footing was measured through a pre calibrated proving ring suspended from the spindle of the jack through an adapter and resting on the footing through a ball bearing. Settlements of the footing were measured by two dial gauges placed in diagonal directions.

Different series of the model tests were conducted on the ring footing supported by the unreinforced (UR) and tire chis (TC) mixed soil layer. In the series of the tests conducted on the tire chips reinforced soil content of the tire chips and depth of the reinforced layer are varied as discussed above.

4. RESULTS AND DISCUSSIONS

Model tests are performed to understand the performance of the tire chips mixed with the black cotton soil. The results presented here are in terms of the percentage improvement in the load with settlement. The impact of the varying parameters like depth of the reinforcing layer and the content of tire chips are presented in following section.

A. Effect of the content of the tire chips

In test series conducted on the ring footing supported by tire chips mixed with black cotton soil. Results obtained from the tests are presented in the Fig. 5. In this series of test tire content are varied from 5-20%. It can be observed from Fig. 5 that due to addition of the tire chips load carrying capacity increases. The performance of the tire chips increases with increase in the tire content upto10% of tire chips content. Further increment in the tire content doesn't contribute in the performance of the tire chips reinforcement. Upto 10% of tire content tire chips mobilize reinforcing action significantly, through surface friction mobilized between soil particles and tire chips. Due to this increment in the load carrying capacity increases. At 20% tire chips content the performance of the tire chips reinforcement is minimum. At 20% tire chips content the amount of tire chips is higher and tire chips are compressible in nature. Due to this reason the load carrying capacity increases. The improvement in the load carrying capacity is 160% at 10% of tire chips content. While the improvement in the load carrying capacity is 90% at tire chips content of the 20%. It can also be observed that the stiffness of soil mixed with 5-10% is higher than the soil mixed with the tire chips with 15-20% tire content. At higher tire content due to large amount of the tire chips compressibility of mix decreases. So stiffness of the reinforced layer decreases with increase in the tire content.

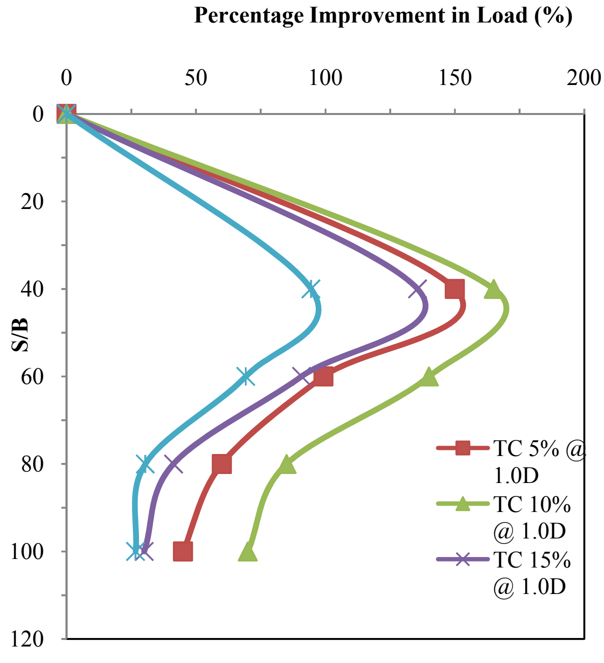

Fig. 5 variationof load improvement with tire content

B. Effect of depth of the reinforced layer

To understand the impact of the depth of the reinforced layer is investigated through varrying the depth of the reinforcing layer. The results obtained is presented in the Fig. 6. It can be observed that the performance of the tire chips reinformcement is maximum at the depth of 0.5 times the diameter of the ring footing. With increase in the depth of the reinforced layer decreases the performance of the tire chips reinforcement. The perofmace of the load carrying capacity increase by 170% when the depth of the footing was 0.5D. While in case when depth of the footing was 1.5D, then the improvement in the load carrying capacity was around 140%. It can be further observed that when the reifnrocement is at depth of the 0.5D the stiffness of soil mixed with tire chips is maximum.

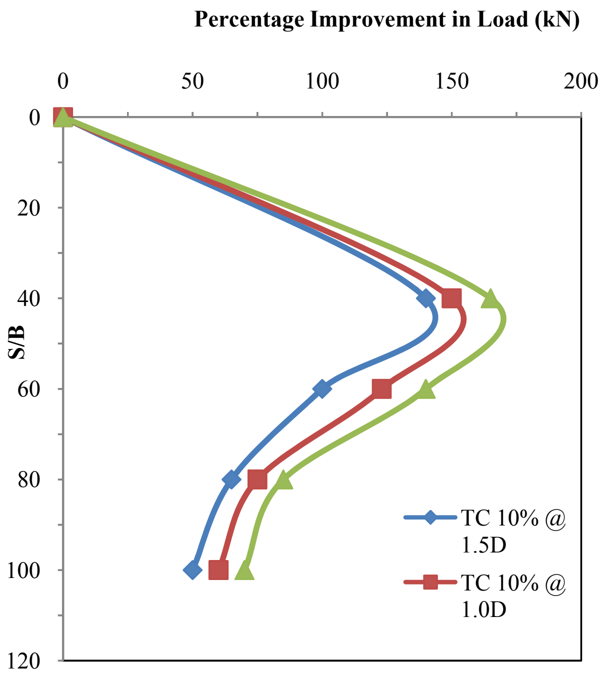

Fig. 6: Variationof load improvement with depth of the tire chips mixed soil

5. CONCLUSIONS

This paper have disused the result of the model laboratory test conducted on the ring footing reinforced by tire chips. The results obtained from the tests have shown that tire chips improve the load carrying capacity by mobilizing friction between soil particles and tire chips. From the results following important conclusions can be drawn.

- Tire chips have potential to improve the load carrying capacity of the soil.
- Performance of the tire chips was optimum when content of the tire chips was between 5-10%.
- Load carrying capacity decreases with increase in the depth of the reinforcement layer. It was found maximum when depth was between 0.5D.
- Tire chips also improve the stiffness behavior of the soil.

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