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Application Of Waste Tyre Rubber In Granular Soils

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Abstract

In this paper an effort has been made to investigate the feasibility of use of waste tyre rubber shreds as soil reinforcement, hence a series of laboratory tests were carried to study the effect of shredded rubber reinforcement having aspect ratio of 5.0 on bearing capacity and settlement of a strip footing on granular soil. The soil has been reinforced with the rubber shreds at various relative densities of 50%, 60%, 70% and 80% provided at different depths of 0.5B, 1.0B, 1.5B and 2.0B. The results shows that BCR (Bearing Capacity Ratio) can be increased up to1.78at a relative density of 50% and depth of reinforced layer at 0.5B. A minimum SRF (Settlement Reduction Factor) of 0.24 has also been observed at same Relative Density and depth of reinforcement. The findings strongly recommend the use of rubber shreds obtained from non reusable tyres as a viable alternative way for improving the soil behaviour, particularly when environmental effect is considered.

Keywords: Bearing Capacity; strip footing; rubber soil mixture; footing settlement; Rubber reinforced soil

1. Introduction

Disposal of recycling tyre poses a major problem world wide.A lot of research work is going on worldwide to cope up with this problem. Huge stockpiles and uncontrolled dumping of tyres, throughout the countries, is a threat to public health and environment. One of the alternative ways of disposing of waste tyre is to use them for geotechnical applications, due to following advantages:

1. It will help in not only saving huge spaces occupied by waste tyre and tubes, but the environmental health hazards will also be reduced.
2. The consumption of natural soil will be reduced, there by rendering cost saving benefits.
3. The various soil properties such as bearing capacity, shear strength, drainage etc. Can be improved by reinforcing it with waste tyre rubber.
4. With the introduction of waste tyre rubber in soil its capacity to absorb and dissipate energy will be enhanced drastically.

But this possible only with the better understanding the behaviour of rubber soil mixture. Ahmed (1993) [1] carried out tri-axial tests on tyre chips soil mixture and contended that, with the increase of chip content, apparent cohesion increases. Edil and Bosscher(1994) [2] performed direct shear test on sand reinforced with tyre strips , and showed that tyre strip reinforcement increases peak shear strength and limits the post peak shear strength loss. Massad et.al (1996) [7] concluded through his studies that the tyre chips can be used as light weight fill material in highway construction. Tatlisoz et.al (1998) [9], conducted large scale direct shear test with tyre chips, sand, sandy silt, and reported that shear strength of soil increases with the increase of tyre content up to 30% by volume. Scrap tyres can also be used as construction materials such sub-grade fill, bridge abutments, and for erosion control. The examples of using as whole as shown by Garga and O'Shaughnessy(2000) [4] in their studies, or as a tyre shred as shown by Okaba et.al (2001) [10], Ghani et.al(2002) [5]. Edinclier et.al (2004)[3], showed that by the addition of 10% of tyre buffing by weight to sand increases the internal friction angle by 22^o-33^o. Mousa F. Atom(2006) [6], conducted a series of tests and concluded that the presence of shredded waste tyre in sand improves internal friction and shear strength of

soil. Yeo Won Yoon et.al(2008) [12], through his studies has shown that bearing capacity increases and settlement is reduced , because of reinforcing effect of waste tyre in sand ..Martin Christ and Park (2010) [8]conducted direct shear test on rubber sand mixes and showed that rubber mix soil have higher compressive,
shear, and tensile strength as compared to pure sand. S. N. Moghaddaset.al(2012) [11], conduct a series of tests on sand reinforced with waste tyre strips . They showed that with the increase of rubber content, thickness of rubber content, and thickness of reinforced soil layer, results in increase of bearing capacity and decrease of settlement.

Though from the above literature review, it is clear that a number of studies have been reported over the effect of waste tyre reinforcement on the behaviour and properties of sand. But the studies on footing supported by waste tyre rubber are limited.

The present study was focussed on

i) Pressure-settlement behaviour of the model strip footing resting on sand reinforced with waste tire strips, at different Relative Densities

ii) The improvement in the bearing capacity at different Relative Densities

2. Materials and Methods

2.1MATERIAL PROPERTIES OF

In this study poorly graded sand was used. The Grain Size distribution is shown in Figure 2.1. Table 2.1, shows physical and engineering properties of the sand used in the test. Based on Unified Soil Classification System (USCS), the sand used in the test is classified as (SP)

Table 2.1 Physical and Engineering Properties of Sand

Property	
$\gamma_{d(max)}$	12 KN/m^3
$\gamma_{d(min)}$	17 KN/m^3
Φ	24^o
D_{10}	220 µ
D_{30}	310 µ
C_c	460 µ
C_u	0.95

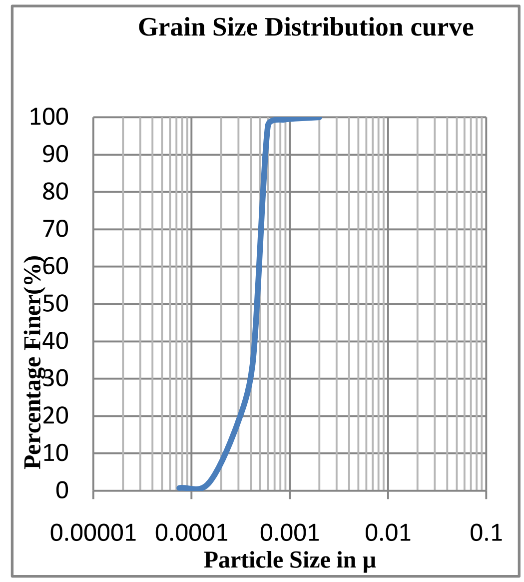

Fig.2.1Grain Size Analysis of Sand Used

2.2MATERIAL PROPERTIES OF WASTE TYRE RUBBER

As an alternative reinforcement material shredded tyre rubber strips were used in this study. They were clean and free from any steel and cord. They were cut from waste tyres into rectangular shape. The nominal size of the tyre shred was 65mmin width and about 300mm in length, so as to have an aspect ratio (ratio of length to width) of approximately 5. The aspect ratio was sochosen, to achieve maximum performance in increasing the bearing capacity of foundation bed and in decreasing the settlement of soil. Table2.2 shows physical and engineering properties of the tyre rubber Strips used in the test. Figure 2.2 shows tyre strips used in the test

Fig.2.2 Tyre Strips used in the Test

Table 3.1 Physical and Engineering Properties of Tyre strips used

Property	Scrap Tyre
Type	Strip Form
Strip Length	300mm
Cross Section	Rectangular 65mmX5mm
Specific Gravity	1.02-1.27
Colour	Black

2.3 Plate load Test

Fig. 2.3.1 Settlement Load tester used

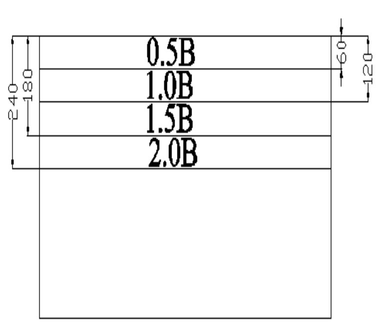

Fig. 2.3.2 Arrangement of reinforcement at different depths

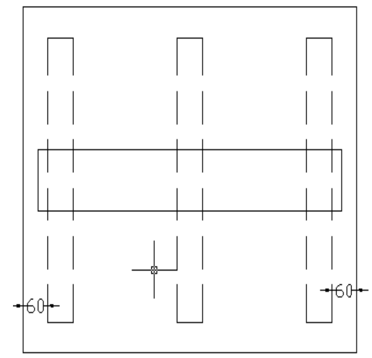

Fig.2.3.3 Arrangement of Reinforcement in Tank

The plate load test was conducted on the sandy soil. The tests were carried out in a tank of size 83cm × 68 cm × 60 cm. The sides of tanks were madeup of 6 mm thick metal sheet.

Strip Footing of size 68cm×12cm×13cm was used. The tank was placed over a concrete base & portal frame of I section was provided with tank.Fig.2.3.1 shows the Settlement load Tester used in test

Soil bed was prepared was prepared in two layers. Top soil layer (h_1) was reinforced with tyre strips arranged as shown in the figure 2.3.2, and bottom unreinforced soil layer (h_2).Depth of top reinforced layer (h_1) was varied from 0.5B to 2B.The arrangement of reinforcement is shown in fig. 2.3.3.

"γ_d," Dry density at the particular relative density (KN/m^3),was calculated using formula

$$I_d = \frac{\gamma d - \gamma d\,(min)}{\gamma d\,(max) - \gamma d\,(min)} \times \frac{\gamma d\,(max)}{\gamma d}$$

Where,γ_d = Dry density at the particular relative density (KN/m^3)

$\gamma_{d\,(min)}$ = Minimum Dry Density (KN/m^3)

$\gamma_{d\,(max)}$ = Maximum Dry Density (KN/m^3)

I_d = Relative Density (%)

The tank was filled in layers of 160mm each. To achieve desired relative density of 50%, 60%, 70% and 80% respectively, each layer was temped and compacted to a specified thickness.

For each RD, First of all, the plate load test was carried out on pure sand sample. Then the test was carried out by placing the reinforcement in the form of strips at 0.5 B, 1.0B, 1.5 B, 2.0 B (Where "B" is width of the footing). The fig.5 shows the general arrangement of

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placing the reinforcement. **This way a total of 20 tests were carried out.**

After preparation of sample, the pressure was applied on the sand with the help of a mechanical arrangement. For each one unit increment of pressure, corresponding settlement was measured using load cell and dial gauges, till the footing started sinking without any further increase of load.

3. RESULTS AND DISCUSSION

The graphs were drawn between pressure and corresponding settlement for sand in unreinforced condition and with reinforcement at different heights, for each RD. Figure no. 3.1.1 shows pressure settlement curves of pure sand at relative density 50%, 60%, 70% and 80%. Figure numbers 3.1.2, 3.1.3, and 3.1.4 and3.1.5 shows pressure settlement curves at relative density 50%, 60%, 70% and 80% respectively.

To express the data, a term bearing capacity ratio (BCR) has been used, which is defined as

$$\mathbf{BCR} = \frac{qur}{qu0}.$$

To express the data, a term settlement reduction factor (SRF) has been used, which is defined as

$$\mathbf{SRF} = \frac{Sr}{So},$$

where S_r and S_o are settlement of reinforced and unreinforced soil at ultimatepressure of unreinforced soil. For comparison, SRF has been calculated at a pressure level corresponding to ultimate bearing capacity of unreinforced sand.

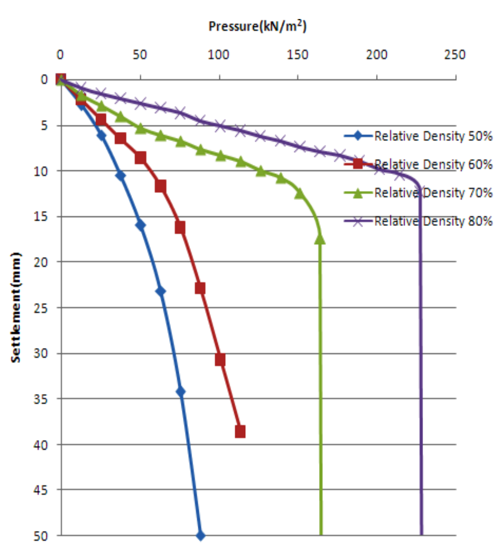

Fig. 3.1.1Pressure settlement curves of pure sand at relative density 50%, 60%, and 70% and80%

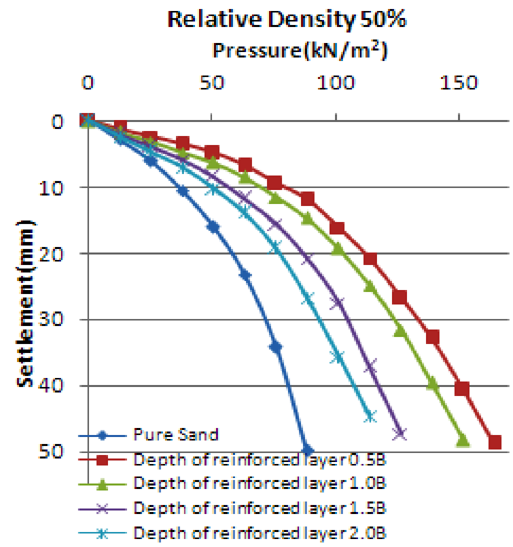

Fig. 3.1.2Pressure settlement curves at relative density 50%, at various depths of reinforcement

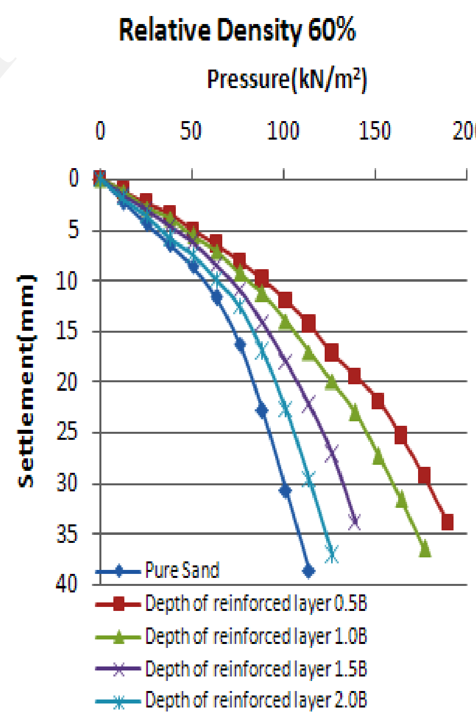

Fig. 3.1.3Pressure settlement curves at relative density 60%, at various depths of reinforcement

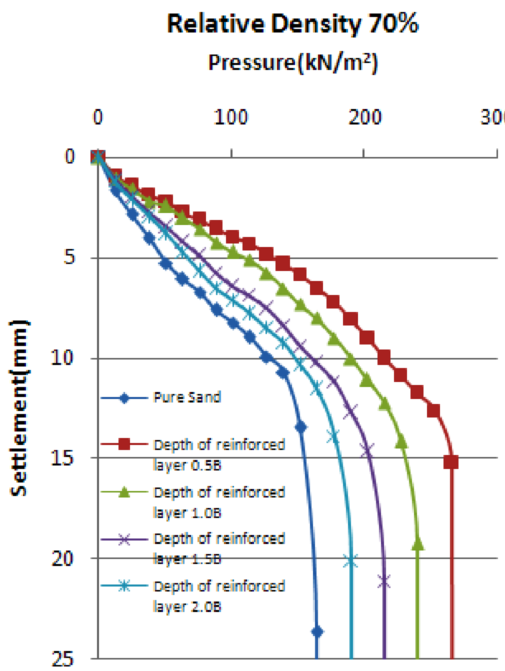

Fig. 3.1.4Pressure settlement curves at relative density 70%, at various depths of reinforcement

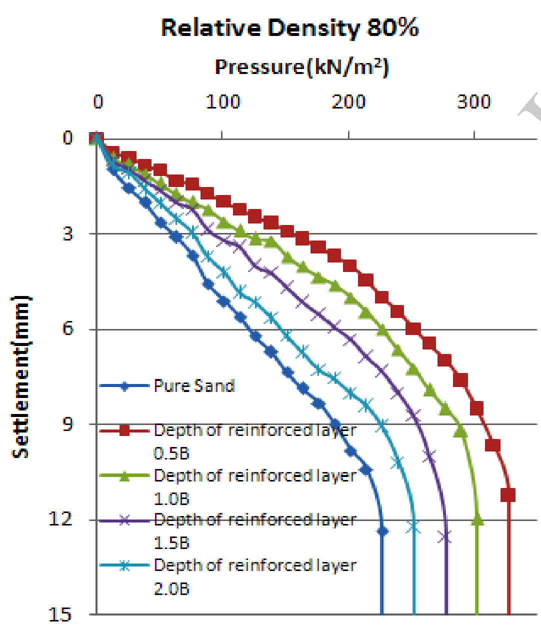

Fig. 3.1.5Pressure settlement curves at relative density 80%, at various depths of reinforcement

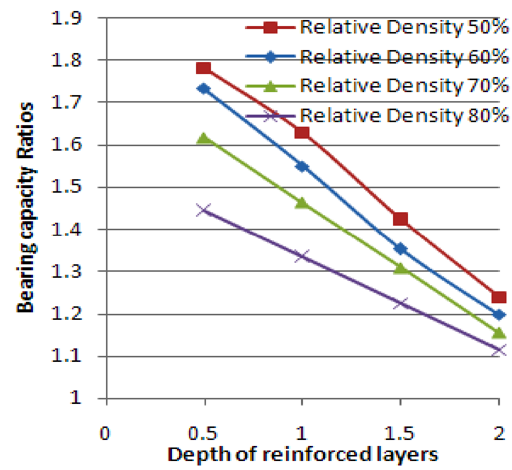

Fig. 3.1.6 Bearing capacity ratios at variousRelativedensities and depth of reinforced Layer

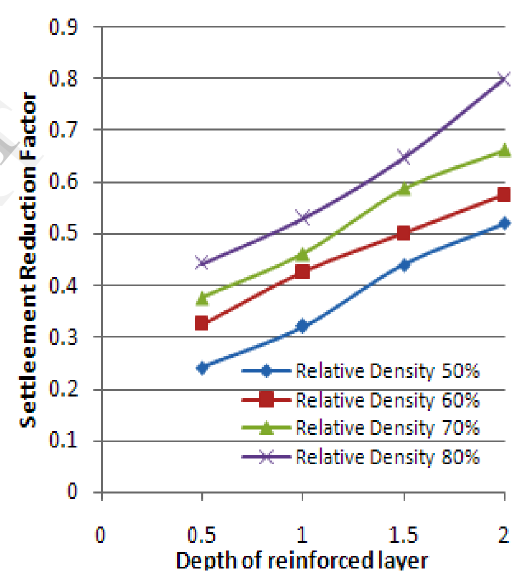

Fig. 3.1.7Settlement reduction factor at variousRelativedensities and depth of reinforced Layer

Table 3.1 Bearing Capacity Ratio (BCR) and Settlement Ratio (SR) at various relative densities and depths of reinforced layer

Relative Density	Depth of Reinforced Layer	BCR	SFR
50%	0.5B	1.78	0.24
	1.0B	1.63	0.32
	1.5B	1.42	0.44
	2.0B	1.24	0.52
60%	0.5B	1.73	0.33
	1.0B	1.55	0.43
	1.5B	1.35	0.50
	2.0B	1.20	0.58
70%	0.5B	1.62	0.38
	1.0B	1.46	0.46
	1.5B	1.31	0.59
	2.0B	1.15	0.66
80%	0.5B	1.44	0.44
	1.0B	1.32	0.53
	1.5B	1.22	0.65
	2.0B	1.13	0.80

Effect of reinforcement on bearing capacity

Figure 3.1.6, shows bearing capacity ratios (BCR) at various Relative densities and depth of reinforced Layer. The graph indicates thatBCR increases with the increase in depth of reinforcement. At a given depth of reinforcement 0.5B, 1.0B and 1.5B and 2.0B,, increase in BCR for RD 50% is observed as 1.78,1.63,1.42 and 1.24, for RD 60% as1.73, 1.55, 1.35% and 1.20, for RD 70% as 1.62, 1.46, 1.31 and 1.15, and for RD 80% as1.44, 1.32,1.22and 1.13 respectively. This result implies that a high concentration of tire strips reinforcement in the foundation soil within a depth of 0.5B below the base of footing can sufficiently reinforce the sand to produce higher bearing capacities.Bearing Capacity Ratio (BCR)at various relative densities and depths of reinforced layer, has been tabulated in Table 3.1

Effect of reinforcement on settlement

Figure 3.1.7 shows Settlement Reduction Factor(SRF) at various Relative densities and depth of reinforced Layer. The graph indicates that SRF decreases with the increase in depth of reinforcement. At a given depth of reinforcement 0.5B, 1.0B and 1.5B and 2.0B,, decrease in SRF for RD 50% has beenobserved as 0.24,0.32, 0.44and 0.52, for RD 60% as0.33, 0.43, 0.50and 0.58, for RD 70% as0.38, 0.46, 0.59and 0.66, and for RD 80% as0.44, 0.53, 0.65and 0.80 respectively This result implies that a high concentration of tire strips reinforcement in the foundation soil within a depth of 0.5B below the base of footing can sufficiently reinforce the sand to produce lowest Settlement Reduction Factor. Settlement Ratio (SR) at various relative densities and depths of reinforced layer, has been tabulated in Table 3.1

Conclusions:

On the basis of the results and discussions on this investigation the following conclusions are drawn:

- Maximum improvement in B.C.R. (Bearing Capacity Ratio) of rubber reinforced soil was obtained as 1.76 times the unreinforced soil at 0.5B.
- BCR decreases with increase in depth of reinforced layer.
- Minimum improvement in SRF. (Settlement Reduction Factor) of rubber reinforced soil was obtained as 0.24 times the unreinforced soil at 0.5B.
- SRF decreases with increase in depth of reinforced layer.

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