Application of Waste Tyre Strips in Granular Soils

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Abstract

In this paper an effort has been made to investigate the feasibility of using waste tyre strip in grid pattern as soil reinforcement.A series of laboratory load tests were carried to study the effect of rubber grid reinforcement on bearing capacity of a strip footing resting on granular soil. Load tests were performed on the soil with RD 50% reinforced with the single grid having size 50cm X 50cm provided at different depths of 1.0B, 1.5B and 2.0B(B=width of footing=10cm). Load tests were also carried with two rubber grids at vertical spacing of 1B. The results show that BCR (Bearing Capacity Ratio) increased by to 1.25 at depth of single reinforced layer at 1B and by 2.04 by using two reinforced layers at 1B-2B. The findings strongly recommend the use of waste tyre strip in form of grids as a viable alternative for improving the soil behaviour, particularly when environmental effect is considered.

Keywords:Bearing Capacity; Strip footing; Rubber Soil mixture; Footing Settlement; Rubber reinforced soil

1.0 Introduction

Soil reinforcement is an effective and reliable technique for increasing the strength and stability of soils. The technique is used today in a variety of applications ranging from retaining structures and embankments to subgrade stabilization beneath footings and pavements. Reinforcement can vary greatly; either in the form of strips, sheets, grids, bars or fibres. Scrap tyres have become a growing disposal problem worldwide, caused by increasing number of vehicles on the roads. Scrap tyres are non-degradable and because of their shape, quantity and compaction resistance, require a large amount of space and stock piling and land filling. Recent statistics in India indicated more than 100 % increase in number of registered vehicles within 10 years. Due to the increase in number of vehicles the amount of scrap tires had increased drastically. Stock piles of scrap tires can result in public health, environmental, and aesthetic problems. It is estimated that 1 to 2 billion scrap tyres have been disposed in huge piles across India and additional 250 million tyres are discarded every year. Almost 30% of the scrap tyres wind up in overcrowded landfills, and thousands more are left in empty lots and illegal tyre dumps. These dumps are serious fire hazard, a breeding ground for rodents and mosquitoes and an unpleasant site. Because rubber tyres do not easily decompose, economically feasible and environmentally sound, alternatives for scrap tyre disposal must be found. To avoid these conditions, it is desirable to reduce the quantity of stock piled scrap tyres through recycling and alternative use. The need to manage scrap tyres has given rise to numerous scrap tyre management programs and brought about laws or regulations. Scrap tyres have been beneficially utilized in many industrial applications. Scrap tyre is beneficially used as a raw material for civil engineering construction. From geotechnical engineering prospective scrap tyres have interesting properties. Tyres have high strength (especially when steel belted), the durability is excellent, the supply is potentially high, the cost is low and density is low. Tyres are manufactured to combine flexibility, strength, resiliency and high frictional resistance. If tyres are reused as a construction material, the unique properties of tyre can once again be exploited in beneficial manner. The benefits of using scrap tyres are particularly enhanced if they can be used to replace virgin construction material made from non-renewable resources.

Various studies have been carried out for understanding the behaviour of rubber soil mixture.

The studies showed that reinforced sand's bearing capacity is more than twice of that of unreinforced sand. Some researchers conducted laboratory plate load test under various conditions such as relative density, embedded depth, number of reinforced layers and size or reinforcement on sand having waste tyres as reinforcing material. Standard Proctor Tests, unconfined compression tests and California bearing ratio reveals that rubber strips/grids can be used as reinforcement for cohesive and cohesion less soil. Many of the researches have been done on the use of tyre shreds/chips in engineering projects. Ahmed (1993) 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) 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. Tatlisoz et.al (1998) 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. Edinclier et.al (2004) showed that by the addition of 10% of tyre buffing by weight to sand increases the internal friction angle by 22^o-33^o. Yeo Won Yoon et.al (2004) conducted laboratory plate load test under various conditions such as relative density, embedded depth, number of reinforced layers and size of a mat and combination type of tyre segments on sand having waste tyres as reinforcing material. From the plate load test results, effectiveness of tyre mat as a reinforcing material could clearly be seen. The effects of reinforcing and settlement reduction are higher at lower sand density.Hataf and Rahimi (2005) conducted a series of laboratory model tests to investigate the using of shredded waste tyres as reinforcement to increase the bearing capacity of soil. They showed , shred contents and shreds aspect ratio are the main parameters that affect the bearing capacity.In addition, the mixtures of sand and tyre rubber particles are materials that exert less lateral earth pressures on retaining structures as compared with those exerted by sand alone. Mousa F. Atom (2006) conducted a series of tests and concluded that the presence of shredded waste tyre in sand improves internal friction and shear strength of soil. Martin Christ and Park (2010) 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. Moghaddas et.al (2012) conducted 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. Naval et.al (2013) performed load tests and triaxial tests on granular soils reinforced with randomly mixed tyre shreds 1.5mm-2.0mm thick. The thickness of reinforced layer was kept as 0.5B, 1.0B, 1.5B and 2.0B (where B is width of footing), it was found maximum bearing capacity improvement was observed at a fibre content of 0.75% with depth of reinforcement 1.5B. The angle of internal friction improved from 28^o to 42^o at the same fibre content.

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 objective of the present study was:

- To study the pressure - settlement behaviour of sandy soil reinforced with waste tyre rubber grid at different depths.
- To study the improvement in the bearing capacity of the soil by placing grid at different depths and by varying the vertical spacing between the grids

A series of laboratory load tests were carried to study the effect of rubber grid reinforcement on bearing capacity of a strip footing resting on granular soil. Load tests were performed on the soil with RD 50% reinforced with the single grid having size 50cm X 50cm provided at different depths of 1.0B, 1.5B and 2.0B(B=width of footing=10cm). Load tests were also carried with two rubber grids at vertical spacing of 1B. The results show that BCR (Bearing Capacity Ratio) increased by to 1.25 at depth of single reinforced layer at 1B and by 2.04 by using two reinforced layers at 1B-2B. The findings strongly recommend the use of waste tyre strip in form of grids as a viable alternative for improving the soil behaviour, particularly when environmental effect is considered.

2.0 Materials and Methods

2.1 Properties of sand used

In this study **poorly graded sand** was used. The table below 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). The engineering properties of sand used in this test are given below:

Table.2.0 Physical and engineering properties of sand used

$\gamma_{d(max)}$	16.89 kN/m^3
γ_d	15.19 kN/m^3
$\gamma_{d(min)}$	14 kN/m^3
I_D	50%
Φ	24^o
D_{10}(Particle size at 10% finer)	220 μ
D_{30}(Particle size at 30% finer)	310 μ
D_{60} (Particle size at 60% finer)	460 μ
C_c (Coefficient of curvature)	0.95
C_u (Coefficient of uniformity)	2.09

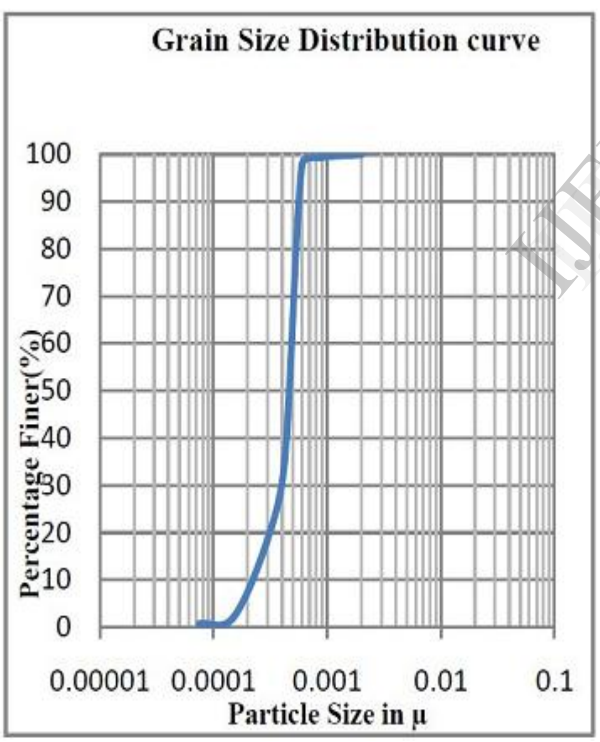

Fig.2.0 Grain Size Distribution Curve

2.2 Properties of waste tyre strips used

As an alternative reinforcement material, waste 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 tyre shreds was about 65mm in width and about 500 mm in length, so as to have an aspect ratio of approximately 8.The aspect ratio was so chosen, to achieve maximum performance in increasing the bearing capacity of foundation bed and in decreasing the settlement of soil. The following table shows physical and engineering properties of tyre rubber strips used in the test.

Table.2.1 Physical and engineering properties of rubber strip

Type	Strip Form
Strip Length	500mm
Strip Width	65mm
Strip Thickness	3.5mm
Cross-section	Rectangular (65mm * 3.5mm)
Specific Gravity	1.02 – 1.27
Colour	Black

The waste tyre rubber strips were attached together with iron nails to form square grid of dimensions **500mm * 500mm**.

Fig.2.1Square Rubber Grid used in the Test

2.3Equipment Used

In the Plate Load Test “SETTLEMENT LOAD TESTER” was used.

Fig.2.2 Settlement Load Tester

This machine uses a special arrangement in which the load is applied uniformly on a strip footing and simultaneous settlements are recorded electronically. The plate load test was conducted on the sandy soil. The tests were carried out in a tank of size **68.5cm × 83 cm × 63 cm**. The sides of tanks were made up of **6 mm** thick metal sheet. Strip Footing of size **60cm × 10 cm × 10 cm** was used. The tank was placed over a concrete base & portal frame of I section was provided with tank.

2.4Test Procedure

The sandy soil which was used in the experiment was first dried in open air for few days. The soil was then filtered with the sieve of size 1.18mm. All the waste particles like stones, other unwanted materials were removed by this process.

The relative density of the sand was set at 50%.Maximum and Minimum Dry Unit weights of sand at 50% relative density were determined. Dry unit weight was obtained from the following expression:

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

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 weight of sand required to be filled in the tank for 60 cm depth of sand layer was calculated by expression:

$W = V * \gamma_d$

Where,

W = Weight of sand

V = Volume of sand upto 60 cm height of tank

Without Reinforcement
The tank was filled with fully dried sand in three layers. And hand tamping was done with the help of tamping rod after laying each sand layer. The depth of each layer was 20 cm and the total depth of the sand layer was 60 cm. The sand layer was levelled.

With Reinforcement
The square grid of waste tyre strip was laid at different depths of sand layer i.e. 1B, 1.5B, 2B, both 1B & 2B, both 1.5B & 2.5B.

The strip footing was brought in contact with the sand layer and load was applied constantly by rotating the lever. Load was increased by increments of 1kN and the corresponding settlements were noted down.

Pressure – Settlement curves are plotted on suitable scale for each case.

3.0 Results and Discussions

No. of load tests were carried on soil of relative density 50%reinforced with tyre strip grip of size 50cm X 50cm at different depths and also with varying vertical spacing when two grids are used.

Results obtained are shown in tabular form:

Table 3.1 Table for values obtained from settlement load tester on sand without reinforcement

LOAD(kN)	PRESSURE(kN/m^2)	CUMULATIVE SETTLEMENT(mm)
1	16.6	1.29
2	33.3	2.31
3	50	3.05
4	66.66	3.75
5	83.33	4.3
6	100	5.35
7	116.6	6.7
8	133.3	8.7

TABLE 3.2 Table for values obtained from settlement load tester on sand with reinforcement at 1B

LOAD(kN)	PRESSURE(kN/m^2)	CUMULATIVE SETTLEMENT(mm)
1	16.66	2.91
2	33.33	5.09
3	50	7.49
4	66.66	24.81
5	83.33	34.04
6	100	40.27
7	116.66	44.66
8	133.33	47.54
9	150	50.66
10	166.66	51.72
11	183.33	52.27
12	200	54.35
13	216.66	55.22
14	233.3	57.92
15	250	60.29
16	266.6	67.89

TABLE 3.3 Table for values obtained from settlement load tester on sand with reinforcement at 1B-2B

LOAD(kN)	PRESSURE(kN/m^2)	CUMULATIVE SETTLEMENT(mm)
1	16.66	2.55
2	33.3	3.98
3	50	5.44
4	66.66	6.91
5	83.33	8.52
5.5	91.66	9.47
6	100	29.96
6.5	108.33	35.25
7	116.66	36.67
7.5	125	38.56
8	133.33	39.51
8.5	141.6	41.22
9	150	42.48
10	166.6	44.27
10.5	175	45.47
11	183.33	46.1
11.5	191.66	47.55
12	200	48.53
12.5	208.33	49.3
13	216.33	51
13.5	225	51.58
14	233.33	52.33
14.5	241.66	52.93
15	250	53.52
15.5	258.33	54.98
16	266.66	56.07
16.5	275	56.38
17	283.33	57.35
17.5	291.66	59.1

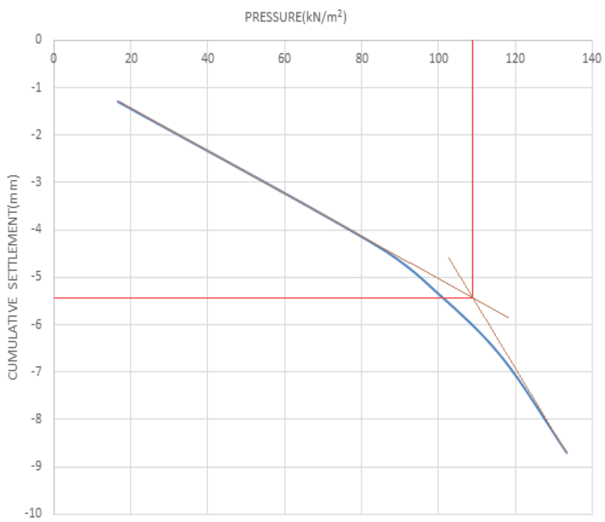

Fig. 3.1 Pressure Settlement Curve of Granular soil Without Reinforcement

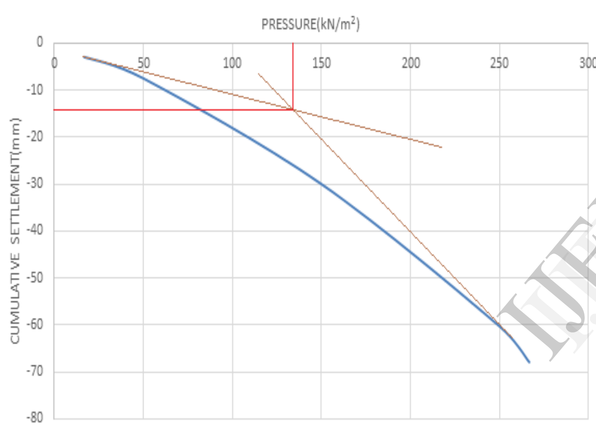

Fig. 3.2 Pressure Settlement Curve of Granular soil With Reinforcement at depth of 1B

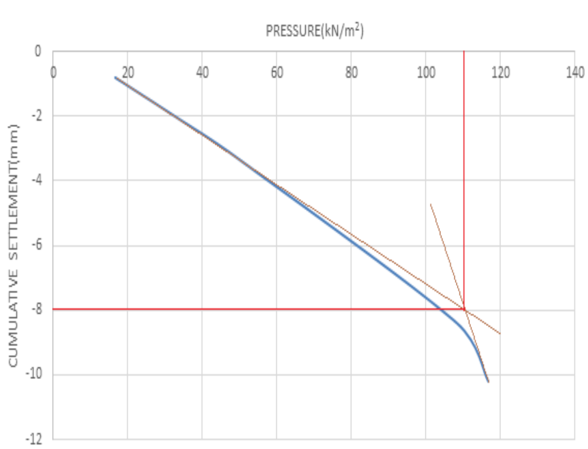

Fig.3.3 Pressure Settlement Curve of Granular soil With Reinforcement at depth of 1.5B

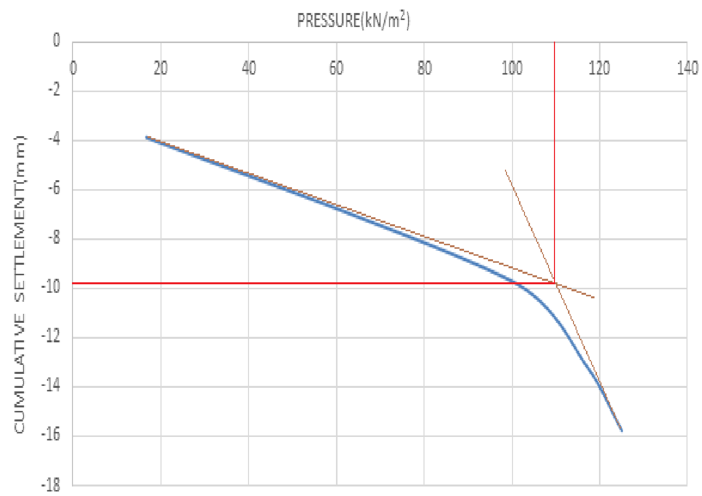

Fig.3.4 Pressure Settlement Curve of Granular soil With Reinforcement at depth of 2B

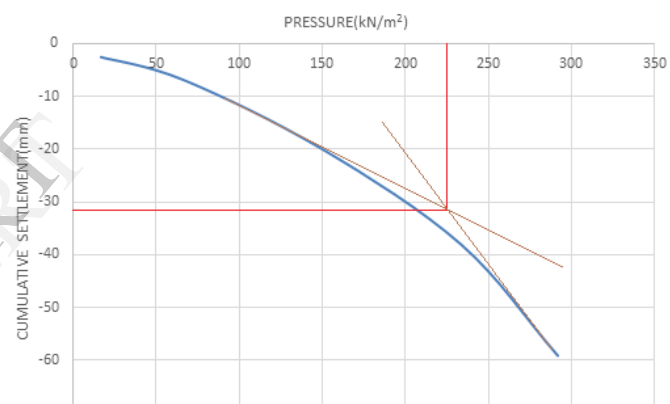

Fig.3.5 Pressure Settlement Curve of Granular soil With Reinforcement at depth of 1B-2B

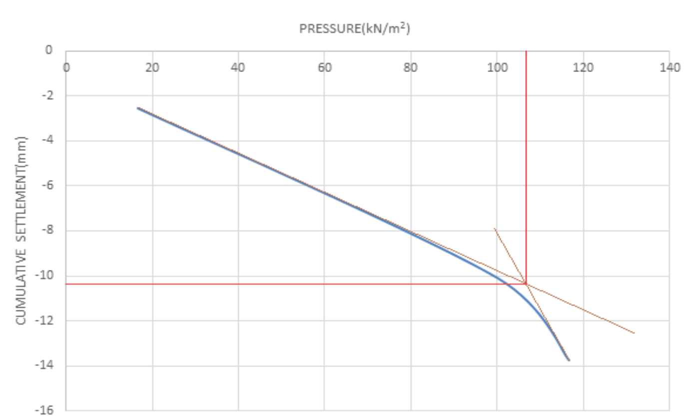

Fig.3.6 Pressure Settlement Curve of Granular soil With Reinforcement at depth of 1.5B-2.5B

Table 3.4.Bearing Capacity, Load Carrying Capacity, BCR values for different conditions

CONDITION	ULTIMATE BEARING CAPACITY (kN/m²)	ULTIMATE LOAD (kN)	BEARING CAPACITY RATIO(BCR)
Unreinforced Sand	108.3	6.498	1
Grid At 1B	136.3	8.178	1.25
Grid At 1.5B	110	6.60	1.01
Grid At 2B	109	6.54	1.006
Grid At 1B-2B	222	13.320	2.04
Grid At 1.5B-2.5B	106	6.36	0.97

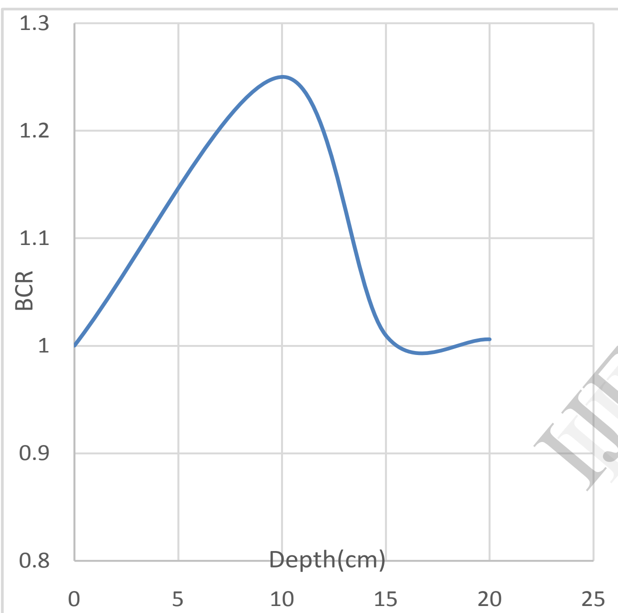

Fig 3.7B.C.R vs Depth of reinforcement

4.0 Conclusions

In this study, a series of laboratory tests have been carried out on strip footing supported on waste tyre grid and unreinforced soil beds. The results have been used and understand potential benefits of reinforcing soil with waste tyre rubber in terms of increased bearing pressure of footing compared with footing on unreinforced bed. Based upon the results, following conclusions are drawn:

- The test results show improvement in the Ultimate Bearing Capacity (UBC) of soil with the inclusion of waste tyre grids at all the depths.
- Maximum improvement in Ultimate Bearing Capacity has been observed at depth of 1B (B is the width of the footing) of single grid, the UBC improved from 108.3kN/m^2 to 136.3kN/m^2 i.e an increase of 25.9%.
- With the application of two grids as reinforcement in sandy soil, the maximum improvement in the Ultimate Bearing Capacity has been observed at depth of top layer of reinforcement of 1B and vertical spacing of 1B, the UBC improved from 108.3kN/m^2 to 222kN/m^2.
- Ultimate Bearing capacity increases with the decrease in depth of reinforcement layer.
- Although there was an increase in ultimate bearing capacity, there were a lot of variation in the settlement.
- Maximum Bearing Capacity Ratio has been observed at depth of 1B (B is the width of the footing) of single grid, the BCR value of 1.25 was obtained.
- With application of two grids as reinforcement, maximum BCR of 2.04 was obtained for reinforced soil at 50% RD and at a depth of top layer of reinforcement of 1B and vertical spacing of 1B.
- BCR decreases with increase in depth of reinforced layer.
- It may be concluded that waste tyre reinforcement in the form of grids is going to be useful for foundations resting on loose soils.

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