IMPROVEMENT OF BEARING CAPACITY OF COHESIONLESS SOILS WITH RANDOMLY DISTRIBUTED WASTE TYRE RUBBER SHREDS

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Abstract: Scrap tyres are undesired urban waste and the volume is increasing every year. Tyres have characteristics that make them not easy to dispose and potentially combustible. Utilizing waste materials as an alternative to using virgin construction material made from nonrenewable resources in civil engineering applications is currently one of the most important environmental issue. The objective of this study is to investigate the feasibility of randomly distributed rubber shreds into cohesionless soil as soil reinforcement beneath the footing. In this research a series of laboratory tests conducted to obtain the bearing capacity of a model footing rested on shredded rubber-reinforced soil with varied percentage of tyre shreds for different thick reinforced sand layer. The results show that the optimum value of rubber content of 5% at footing settlement level of 5%, the maximum improvement in bearing capacity of rubber-reinforced bed is obtained 2.60 times of the unreinforced bed. This value of improvement is achieved using the optimum thickness of reinforced layer of 0.5 times of footing width. The results indicate that the use of waste tyre rubber shreds have a good potential to improve the soil bearing capacity of cohesionless soils particularly when environmental interest is considered.

Keywords: Bearing Capacity; Rubber-reinforced soil; Reinforced sand layer; tyre rubber shred content; Footing settlement; square model footing.

Introduction: Disposal of recycling tyre poses a major problem worldwide. A lot of research work is going on worldwide to cope up with this problem. Tyres have characteristics that make them not easy to dispose, and potentially combustible. 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. (5) Non-biodegradable and thus more durable. (6) Inexpensive compared to other lightweight reinforcing materials for granular soils. Reinforced earth technique has been gaining popularity in the field of geotechnical engineering due to its highly versatile and flexible nature. The application of waste tyres in various forms has been recently developed in reinforcing soil for a variety of geotechnical applications ranging from retaining structures and earth embankments, asphalt pavement and paving system, foundation beds and other applications. Therefore, using recycled materials, particularly wastes tyres when mixed/combined with soil is becoming more popular due to the shortage of natural mineral resources and increasing waste disposal costs. However, with increasing the use of waste tyres in geotechnical applications, a need for further understanding of the behavior of rubber–soil mixture/combination is required.

Literature review: Yoon et al. (2004) [1] presented the beneficial use of sidewalls of waste car tyres as reinforcing material in sand from laboratory plate load tests. Hataf and Rahimi (2005) [2] carried out a series of laboratory model tests to investigate the bearing capacity of shallow footing directly supported on sand reinforced with randomly distributed tyre shreds (i.e. there was no soil cap over the rubber–soil mixture). Their results indicated maximum bearing capacity for rubber-reinforced bed, without considering the settlement limit criterion, was obtained around 3.4 times of the unreinforced bed at shred content of 40% by volume and dimensions of 3-12 cm (aspect ratio of 4). Mousa F. Atom (2006) [3] conducted a series of tests and concluded that the presence of shredded waste tyre in sand improves internal friction and shear strength of soil. Lee and Roh (2007) [4] used recycled tyre chips on the culvert walls in backfill areas to reduce the dynamic earth pressure induced by the compaction loading as well as to improve the characteristics of compacted soils. Yeo Won Yoon et.al (2008) [5] through his studies has shown that bearing capacity increases and settlement is reduced, because of reinforcing effect of waste tyre in sand. T. Tanchaisawat, (2010) [6] presented the interaction between the geogrid and the tyre chip–sand mixture numerous experiments including index tests, compaction tests, pullout tests, and large-scale direct shear tests were conducted. S.N. Moghaddas Tafreshi (2012) [7] investigated that the rubber-soil mixture can exhibit a greater capacity for energy absorbency than soil alone under cyclic loading and tends to decrease the stress and shocks transferred into the ground. Zena Hadi Alqaissi, (2012) [8] reported on the tyre chip mixed randomly with various percentages by weight up to 30% of sand and two different sizes of tyre chip. Laboratory California Bearing Ratio (CBR) and other laboratory model tests are conducted to investigate the improvement of bearing capacity and control settlement of strip footing on sandy soil. Rajwinder Singh Bansal, 2013 [9] investigated the feasibility of use of waste tyre rubber shreds as soil reinforcement and 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. To promote the recycling of tyre wastes on a large-scale in geotechnical applications where bulk utilization of waste materials is possible, in the present study, experimental results to investigate the response of square footings built on shredded rubber-reinforced soil are presented.

Material used :

Soil-The natural granular soil passing through 4.75 mm sieve was used as natural ground, soil cap, and in mixture of rubber–soil as reinforced. The Grain Size distribution is shown in Figure 1 and Table 1 shows physical and engineering properties of the sand used in the test. Based on Unified Soil Classification System (USCS) the sand used in is classified as poorly graded sand (SP) [11].

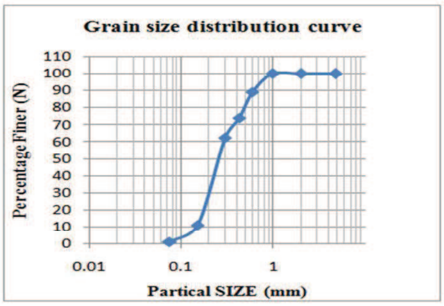

Fig.1. Grain Size Analysis of Sand Used

Fig. 2. shredded tyre rubbers used in this study

Table I. Physical and Engineering Properties of Sand		
Sr.No.	**Property**	**Value**
2	Coefficient of uniformity, Cu	2.09
3	Coefficient of curvature, Cc	1.02
4	Effective grain size, D_{10} (mm)	0.140
5	D_{30} (mm)	0.205
6	D_{60} (mm)	0.293
7	Minimum dry density, $\gamma_{d\,min}$ in gm/cm^3	1.46
7	Maximum dry density, $\gamma_{d\,max}$ in gm/cm^3	1.67
10	Maximum void ratio, e_{max}	0.80
11	Minimum void ratio, e_{min}	0.58
12	Moisture content (%)	0

Shredded tyre rubbers-Shredded tyre rubbers used in this study, as an alternative reinforcement material was clean and free of any steel and cord. They are provided cutting from waste soft tyres of motorcycle with a special cutter into rectangular shape. Table 2 shows physical and engineering properties of the tyre rubber shreds used in the test. Figure 2 shows tyre shreds used in the test.

Experimental setup and test: The plate load test is conducted on the sandy soil. The tests were carried out in steel tank of size 120cm×90cm×90cm. The test setup is shown in fig. 4. The sides of tanks were made up of 6 mm thick metal sheet. A square mild steel plate of size 20X20 cm having a thickness of 2 cm was used as a test footing. Sand was filled in the tank with $\gamma_{d\,max}$ = 1.67gm/cm^3 by using a sieve of 4 mm opening size. Sand with reinforcement and without reinforcement is filled in layers of 10 cm with proper compaction to achieve the desired density in tank. The tank is filled upto 80 cm. preparation of sand and reinforcement layer is shown in fig. 4. After preparation of sample, the load is applied on the sand with the help of a mechanical arrangement. For each one unit increment of load, corresponding settlement is measured using load cell and dial gauges, till the footing started sinking without any further increase of load. This way a total of 10 tests were carried out for varied rubber soil reinforced layer thickness (h_{rs}/B) = 0.25, 0.5 and 1.0 with varied percent with rubber content R_C (%) = 2.5, 5.0 and 7.5. For every test of sand is prepared in layers freshly.

Table II. Physical and Engineering Properties of Sand		
Sr.No.	Parameters	Value
1.	Total unit weight (KN/m3)	5.70
2.	Thickness (mm)	(2-5)
3	Length (mm)	40-50
4	Width (mm)	10
5	aspect ratio	4-5
6	Ultimate tensile strength, T_u (kg/cm^2)	52

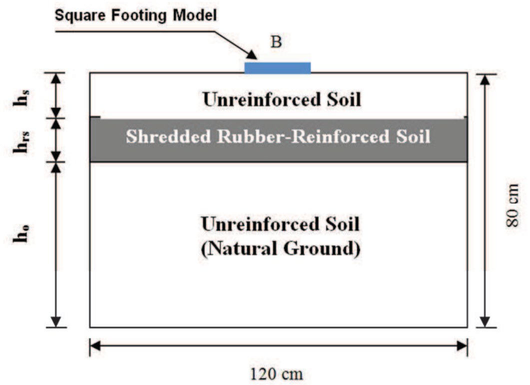

Fig.3 Geometry of foundation bed

Fig. 4. Plate Load Test Setup

Analysis of tests and Results: The result figures are presented below gives load-settlement response of the unreinforced and reinforced foundation beds obtained varying the thickness of rubber-reinforced soil (i.e. h_{rs}/B= 0.25, 0.50 and 1.0), h_{rs}/B at the content of tyre shreds of 2.5%, 5% and 7.5%. The performance improvement due to the provision of reinforcement in the soil bed has been investigated with special emphasis on the footing settlement level on the improvement in bearing capacity of footings for the range of footing settlement less than 6% of footing width.

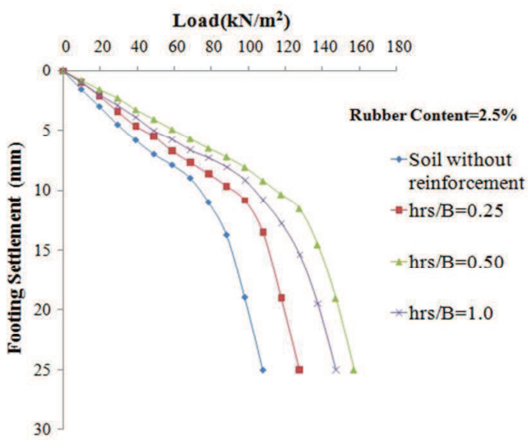

Fig. 5. Load-Settlement curve at Rc=2.5%

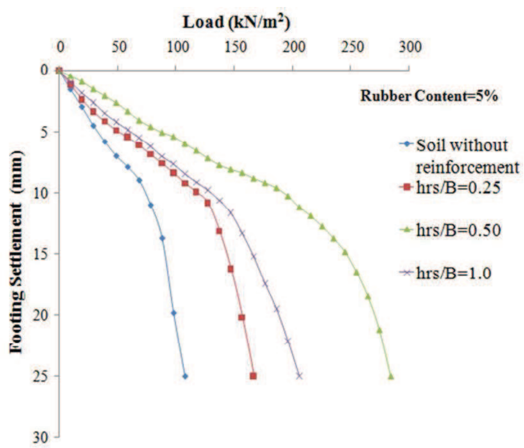

Fig. 6. Load-Settlement curve at Rc=5%

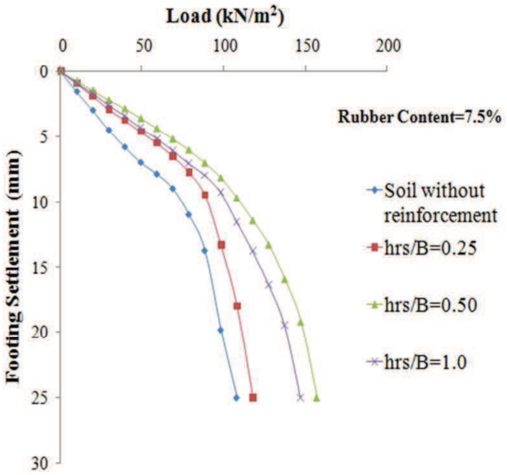

Fig. 7. Load-Settlement Curve at Rc=7.5%

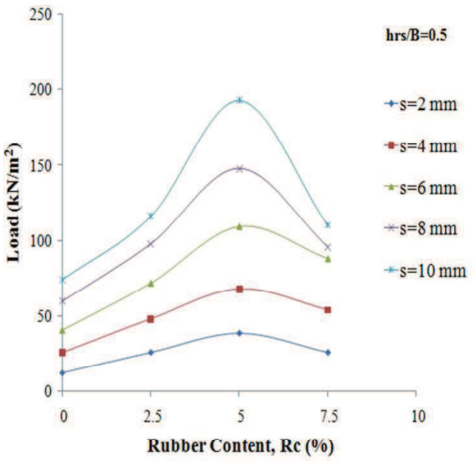

Fig. 8. Load-Rubber content curve at h_{rs}/B=0.5

The optimum value of the rubber content: The bearing pressure obtained at at settlement, s = 10 mm for hrs/B= 0.5 (Fig. 8), are about 74 kN/m2, 116 kN/m2, 193 kN/m2, and 110 kN/m2 for 0%, 2.5%, 5%, and 7.5% of rubber content, respectively. Likewise results are calculated for hrs/B=0.25 and hrs/B=1.0 and also curve figures would drawn but in this paper only figures and results shown for hrs/B=0.5 which is optimum thickness. The increase in performance improvement with rubber content of 5% could be due to the available competent reinforced layer beneath the footing. The decrease in bearing capacity after optimum content of rubber may be attributed to swapping the soil grains with soft material, like rubber, and also possible increasing the void ratio of mixture tends to the compressibility of mixture consequently leading to increase in the footing settlement. It may be expected when the rubber content increases to more than 7.5%, the bearing pressure of footing leads to less than the bearing pressure of unreinforced bed.

Optimum value of the thickness of rubber-reinforced soil (hrs): For 5% rubber content the bearing pressure increases as 74 kN/m2, 118.5 kN/m2, and 193 kN/m2 130.5 kN/m2 for hrs/B = 0, 0.25, 0.5, and 1 of rubber-reinforced layer thickness ratio (hrs/B) for settlement, s = 10 mm from Fig. 9. Similarly for RC=5% and RC=7.5% results obtained. Results reveal the maximum improvement in the bearing pressure of footing have been obtained at optimum thickness of rubber reinforced soil layer (hrs/B = 0.5) and when the thickness of rubber-reinforced soil layer reaches around 1.0 times of the footing width, the reinforcing efficacy of mixture becomes negligible. Therefore, it would be expected that the increase in the thickness of rubber–soil mixture more than 1.0 times of the footing width (hrs/B > 1.0) leads to more significant reduction in bearing pressure value and more significant enhancement in footing settlement value.

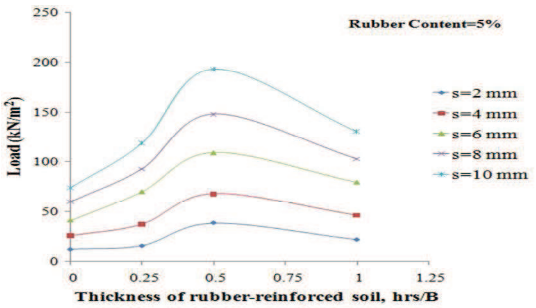

Fig. 9. Load- h_{rs} curve at Rc=5%

Summary and Conclusions: The test results have been used to assess and understand the potential benefits of reinforcing soil with rubber shreds in terms of the increased bearing pressure of footing compared with footing on unreinforced beds. Based on the results obtained, the following conclusions are derived:

(1) The results prove the usefulness in recycling of tyres waste in geotechnical aspects of waste management. These lead to overall saving in

competent soil material costs and re-use of tyres waste.

(2) The results strongly suggest the re-use of tyre waste in the form of shredded rubber mixed with soil as reinforcing elements beneath the footing. From the results of tests, the bearing capacity of footing increases with increase in the rubber content, the thickness of rubber-reinforced soil layer up to their optimum values, after which the bearing pressure decreases.

(3) The optimum percentages of shredded waste tyre rubber are measured around 5% of the total volume of soil-rubber mixture.

(4) The optimal thickness of the rubber-reinforced soil layer to achieve the maximum improvement in bearing capacity of footing is measured to be approximately 0.5 times of the width of the footing. More increase in the thickness of rubber–soil mixture than its optimum value increased the compressibility and the settlement of foundation bed, and consequently the reduction in reinforcing effect.

(5) At the settlement 10 mm the maximum improvement in bearing capacity is observed as the value of bearing capacity of footing reaches around 2.60 times of the unreinforced bed. Based on the above findings, it can be concluded that the use of shredded tyre-soil mixtures as reinforcement layer in foundation bed beneath the footing is very promising and should be promoted. Conceivably, the results of this study could be extended in pavement project subjected by repeated load similar to traffic load in future study. Additionally, this use is beneficial to the environment in that a waste material is recycled.

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