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Experimental study of bearing capacity of strip footing on sand slope reinforced with tire chips

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Abstract. Tire chips and tire chips-soil mixtures can be used as alternative fill material in many civil engineering applications. In this study, the potential benefits of using tire chips as lightweight material to improve the bearing capacity and the settlement behavior of sand slope was investigated experimentally. For this aim, a series of direct shear and model loading tests were conducted. In direct shear tests, the effect of contents of the tire chips on the shear strength parameters of sand was investigated. Different mixing ratios of 0, 5, 10, 15 and 20% by volume were used and the optimum mixing ratio was obtained. Then, laboratory model tests were performed on a model strip footing on sand slope reinforced with randomly distributed tire chips. The loading tests were carried out on sand slope with relative density of 65% and the slope angle of 30°. In the loading tests the percentage of tire chips to sand was taken as same as in direct shear tests. The results indicated that at the same loading level the settlement of strip footing on sand-tire chips mixture was about 30% less than in the case of pure sand. Addition of tire chips to sand increases *BCR* (bearing capacity ratio) from 1.17 to 1.88 with respect to tire chips content. The maximum *BCR* is attained at tire chips content of 10%.

Keywords: tire chips; sand slope; bearing capacity; model test

1. Introduction

Millions of scrap tires are discarded annually in the world, the bulk of which are currently landfilled or stockpiled. The storage of these tires is undesirable for many reasons. They represent a waste of natural resources and a public health hazard. Also, landfilling of discarded tires is becoming impractical due to the rapidly decreasing disposal capacity of existing landfills. The best way to minimize the landfilling and stockpiling of scrap tires is to find alternative uses. One of the uses for scrap tires is in civil engineering applications. Based on the engineering properties such as durability, strength, and high frictional resistance soil-tire mixtures can be used as a construction materials for highway embankments, hydraulic barriers and playground as well as lightweight fill material. Another potential use of scrap tires can be in soil improvement. Shredded scrap tires can be mixed with poor quality soils to improve their engineering properties for civil engineering

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applications. In geotechnical applications, soil-tire mixtures can be used as a fill material for embankments and for reconstruction of unstable or failed slopes. By doing so, the growing concern of solid waste and related disposal problems will be minimized (Guleria and Dutta 2012).

Most of the previous studies concerning the soil-tire mixtures have mainly concentrated to determine the engineering properties of pure tire and/or various mixtures of tire with sand. Ahmed (1993) characterized the shear strength (τ) of mixtures using large-scale triaxial specimens. The results showed that mixtures with less than 38% (by weight) of tire shreds have good compaction characteristics, low unit weight, adequate compressibility, high shear strength, and good drainage characteristics. Direct shear tests to determine the shear strength of shredded tire material were performed by Humphrey *et al*. (1993). An angle of friction (ϕ) of about 23° was found and the cohesion (c) of the material was about 55 kPa. Edil and Bosscher (1994) characterized tire shred–soil mixtures with varying tire shred contents using large-scale direct shear tests. They concluded that tire shred inclusions improve the shear strength of tire shred–sand mixtures, especially for low and intermediate confining pressures. Foose *et al*. (1996) carried out an extensive study on sand reinforced with shredded waste tires of different sizes. They reported that the Mohr strength envelopes were influenced by shred contents, normal stress (σ) and sand matrix unit weight. Wu *et al*. (1997) reported higher friction angles from the results of triaxial compression tests, with values ranging from 45° to 60°. Tatlisoz *et al*. (1998) carried out a series of large scale direct shear tests with sand-tire chips and sandy silt-tire chips mixtures. They showed that sand-tire chips mixture had an increasing behavior of shear strength as the volume of the tire chips increased up to 30%, whereas the sandy silt-tire chip mixture did not have a change in the angle of internal friction, but just an increase in the cohesion. Lee *et al*. (1999), in assessing the stress–strain–volume change response in triaxial tests on sand; tire chips and sand–tire chip mixtures indicated that the response of sand–chip mixtures is intermediate between those of sand and pure tire chips. Edincliler *et al*. (2004) conducted the large scale direct shear tests sand-tire buffing mixtures. It is concluded that 10% by weight tire buffing addition to sand alters the deformation behavior of the mixture by stiffening the material at low strains and softening the mixture at large strains. Zornberg *et al*. (2004) conducted an experimental study using a large-scale triaxial apparatus with the goal of evaluating the optimum dosage and aspect ratio of tire shreds within granular fills. They reported that the optimum tire shred content was approximately 35%. Ghazavi and Sakhi (2005) studied the effect of size of tire shreds on shear strength parameters of sand reinforced with shredded waste tires. They found that shred content, shred width, shred aspect ratio for a given width, compaction, and normal stress are influencing factors on shear strength of the mixtures. Attom (2006) conducted direct shear tests to study the shear strength behavior of sand–shredded tire mixtures under specific conditions. They found that the addition of shredded waste tires increased both the angle of internal friction and the shear strength of the sands.

The experimental investigations mentioned above, showed that scrap tires can be used to improve the mechanical properties of the sand. Inclusion of these materials into the sand has a reinforcing effect. Also, it is clear that tire content, aspect ratio, and normal stress are effective factors on the shear strength of the mixtures.

Although numerous studies concerning to determine the engineering properties of the soil-tire mixtures have been carried out, investigations on the bearing capacity of a footing on soil-tire mixtures are very limited. Few studies on the bearing capacity behavior of strip footings on a soil-tire mixture include works done by Abdrabbo *et al*. (2005) and Hataf and Rahimi (2006). Abdrabbo *et al*. (2005) conducted laboratory tests on a strip footing supported by sand-tire chips mixture. The study was carried out on sand with relative densities (D_r) of 50%, 75%, and 90%. The percentage of tire chips to sand was taken as 5%, 10%, and 15% by weight. They reported that the settlements (s) of the footing on sand-tire chips mixture was about 30% less than in the case of pure sand. Most importantly, the ultimate bearing capacity (q_u) of sandy soil noticeably increased up to 7 times its value in the case of pure sand. Hataf and Rahimi (2006) reported the results of an experimental study of strip footing located on sand reinforced with tire shreds. It is shown that increasing addition of tire shreds to sand increases bearing capacity ratio from 1.17 to 3.9 with respect to shred content and shreds aspect ratio. It should be noted that both studies were conducted on a strip footing on level grounds. However, there are many circumstances where foundations must be built on or near a slope. Due to the land limitation, architectural and economical purposes, structures are generally placed on the slope crest or at a setback distance from the slope crest. Examples include abutments of bridges supported on approach embankments, foundations on electrical transmission towers and some buildings.

The main objective of this study is to investigate the feasibility of using tire chips as reinforcement to improve the settlement and the bearing capacity of strip footing on sand slope. Thus a series of direct shear and laboratory loading tests have been carried out on sand reinforced with randomly distributed tire chips to determine the effects of tire content on the behavior of reinforced soil.

2. Experimental investigation

2.1 Materials used

The soil used for the tests was uniform, clean and fine sand obtained from Cakit River bed. The sand was washed, dried and sorted by particle size. The particle size distribution was determined using the dry sieving method and the results are shown in Fig. 1. Using the Unified Soil Classification System (*USCS*), the material was determined to be poorly graded sand (*SP*). The maximum and minimum dry densities ($\gamma_{d\max}$, $\gamma_{d\min}$) of the sand were measured and corresponding values of the minimum and maximum void ratios ($e_{\max}$, $e_{\min}$) were calculated. Table 1 summarizes the general physical characteristics of the sand.

The pure sand specimens were compacted to achieve target sand unit weight value that corresponds to relative density of D_r = 65%. The target sand unit weight was achieved by calculating the required weights for the constant volume of the direct shear box. Sand specimens were compacted by tamping using a steel rod until the desired sand unit weight was reached. The target sand unit weight value used in this study (17 kN/m^3) is described herein using the relative density to which these unit weight value corresponds in sand specimens (D_r = 65%, medium dense).

Tire chips used in the study were obtained from a local tire manufacturing plant. They were mechanically processed from steel-belted automobile tires by manually cutting using a special cutter. The tire chips did not have any metal pieces in them. Chips having lengths ranging from 15-20 mm were used.

The minimum and the maximum unit weights of tire chips were determined using compaction method. First, the mold was filled with the material without any compaction thus the loosest state of the sample was achieved. Secondly, the mold was filled layer by layer with the same sample. Sample layers were then compacted by a dynamic method equivalent to standard Proctor energy.

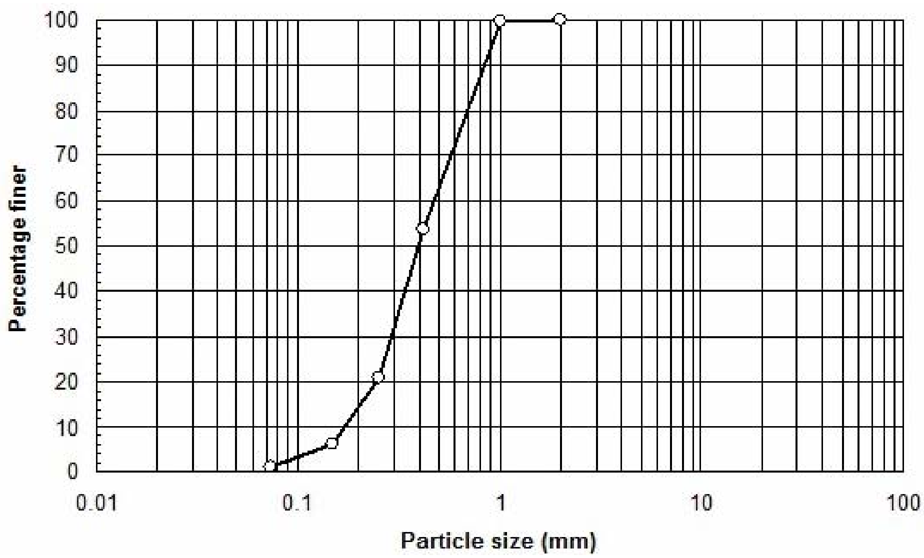

Fig. 1 Grain size distribution of the model sand

Table 1 Properties of sand bed

Parameter	Value
Coarse sand fraction (%)	0.0
Medium sand fraction (%)	46.4
Fine sand fraction (%)	53.6
D_{10} (mm)	0.18
D_{30} (mm)	0.30
D_{60} (mm)	0.50
Uniformity coefficient, C_u	2.78
Coefficient of curvature, C_c	1.00
Specific gravity, γ (kN/m^3)	2.68
Maximum dry unit weight, $\gamma_{d\max}$ (kN/m^3)	17.9
Minimum dry unit weight $\gamma_{d\min}$ (kN/m^3)	15.5
Maximum void ratio, $e_{\max}$	0.729
Minimum void ratio, $e_{\min}$	0.497
Classification (*USCS*)	SP

During filling it was compacted well by a hammer. The tests were repeated three times to verify the test data. Using the obtained data, the minimum and maximum densities of the sample were obtained by calculating the weight of the sample per volume of the mold. The minimum and maximum unit weights of tire chips obtained from compaction tests were 2.6 and 5.8 kN/m^3, respectively. After completing finding out the unit weights of the samples, the maximum and minimum densities of the samples were evaluated and a value between these values were chosen and thus the required weight for the samples were calculated by multiplying the density by the previously known shear box volume.

Tire chips-sand specimens were prepared by mixing the sand and tire chips before placing them into the shear box and same compaction method used to prepare pure sand specimens. One of the factors that may influence the results of the experiments is segregation. Edil and Bosscher (1994) conducted some experiments on sand-tire chips and sand-tire shred and they observed that when the ratio of sand to tire chips was low in the mixture (for example, less than 30% based on volume), segregation happened and sand tended to set in the bottom of the mold. They found that when the amount of sand is high, segregation does not happen. In this study, the amount of sand is high (95%, 90%, 85% and 80%) for all mixture ratios. To avoid segregation during mixing the samples, the maximum care was taken by keep mixing and observing the mixture from the beginning till pouring them into the shear box and model box. No evidence of segregation was observed and in order to be sure that the procedure was done correctly and the results are real and accurate, several tests were repeated at least one more time.

2.2 Direct shear tests

To study the shear strength behavior of sand-tire mixtures, a series of direct shear test was carried out on sand mixed with different percentage of tire chips. The dry sand was mixed with 0, 5, 10, 15, and 20% of tire chips. Specimens were prepared for the direct shear tests at 65% relative compaction by calculating the required weights for the constant value of the direct shear box. The tests were performed on a direct-shear device with a 6 cm × 6 cm square and 3.5 cm height shear box. Different normal loads were applied on the specimen in the direct shear tests. A shear rate of 1 mm/minute was used. The direct shear tests were conducted in accordance with American Standard for testing and Materials D-3080 (ASTM 1985).

2.3 Model loading tests

A series of laboratory model tests were performed in a test box made of a steel frame with inside dimensions of 1.140 m (length), 0.475 m (width) and 0.500 m (depth) as shown in Fig. 2. The bottom and vertical edges of the box were stiffened using angle sections to avoid lateral yielding during soil placement and loading of the model footing. The two sidewalls of the test box were made of 20 mm thick glass to see the sand sample during preparation and observe the sand particle deformations during the tests. The box was enough rigid to provide plane strain conditions for all model tests. Static vertical loads were applied to the model footings by a motor-controlled hydraulic jack system. The system attached to the loading frame located above the test box has a loading rate of 0.5 mm/min. An electronic 15 kN capacity load cell was used to measure applied loads. Settlements of the footing were measured using two linear variable displacement transducers (*LVDTs*) located at the two corners of the model footing. The load cell and the displacement transducers were connected to data acquisition system (*ADU*) for recording and data handling. Loading tests were carried out on a model strip footing of 70 mm in width (B), 465 mm in length and 20 mm in thickness fabricated from mild steel with a hole at its center to accommodate a ball bearing. The lengths of the footings were made almost equal to the width of the test box of the tank to maintain plane strain conditions.

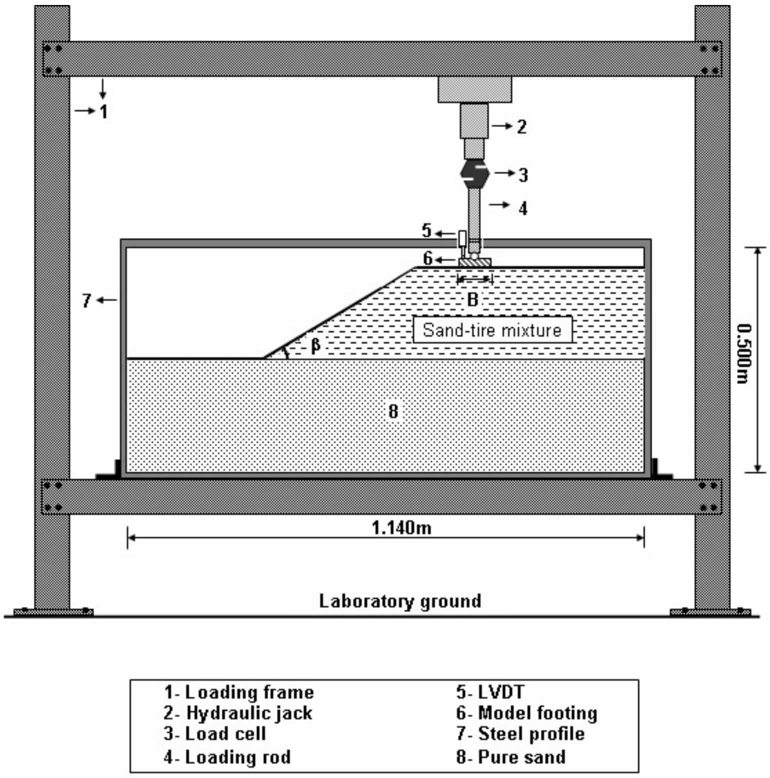

Fig. 2 Schematic view of the experimental set-up

In the tests, the height of the sand-tire mixture (H) was equal to the two times of the footing width ($H = 2B$). The percentages of tire chips in the loading tests were 0, 5, 10, 15, and 20% by volume. Model sand slope with slope angle of $\beta = 30°$ and relative density of $D_r = 65\%$ were prepared by using the same compaction procedure in layers of 50 mm thick sand. The inner surfaces of the test box were marked at 50 mm intervals to make easy the preparation of the sand bed in layers and the geometry of the slope was marked on the glass walls for reference. First, the sand was compacted in layers up to slope toe with pure sand. Then, the weights of sand and tire chips were measured with respect to the desired tire chips contents and mixed carefully with a spade. Special care was taken to mix thoroughly the tire chips and the soil, in order to produce a reasonably uniform tire chips–sand mixture. A special adjustable apparatus to get the predetermined slope angle developed in this study was placed to obtain the sloping surface. The process continued layer by layer until the height of the sand-tire mixture was reached. Great care was given to level the slope face using special apparatus so that the relative density of the top surface was not affected. The model strip footing was then placed on the surface of the compacted sand and finally the load was applied until reaching failure.

A test on unreinforced soil (without a sand–tire chips mixture) was performed to provide a reference bearing capacity that allows quantification of the improvements due to layers of tire chips reinforcement. Several tests were repeated carefully at least twice to examine the performance of the apparatus, the accuracy of the measurements, the repeatability of the system, the reliability of the results, and the consistency of the data. The results of multiple trial tests exhibited maximum differences of around 5%. This difference was considered to be small and is subsequently neglected.

3. Results and discussion

3.1 Direct shear test results

Direct shear tests were carried out to determine the shear strengths of sand alone and sand-tire chips mixtures under different normal stresses. The failure envelopes and the internal friction angles versus sand-tire chips mixtures with the percentages of 0, 5, 10, 15, and 20% are shown in Figs. 3 and 4, respectively.

The effect of tire chips content on the shear strength of sand-tire chips mixtures is illustrated in Fig. 3 which shows the shear strength envelopes of five series with the same relative density (D_r = 65%) but varying tire chips contents. The shear strength envelope for pure sand (D_r = 65%) included in Fig. 3 as a reference. Fig. 3 shows that the influence of tire chips on sand is beneficial. The results indicate that shear strength increases with increasing tire chips content reaches a maximum for a tire chips content of 15% and then decreases for tire chips content beyond this value. The shear strength under normal stress of 28 kN/m^2 increases from 30.96 kN/m^2 at 0% to 31.77 kN/m^2, 34.32 kN/m^2, 39.83 kN/m^2 and 38.46 kN/m^2 at tire chips contents of 5, 10, 15, and 20%, respectively. The shear strength decreases when the tire chip content increases beyond 15% because the sand-tire chip mixture behaves less like reinforced soil and more like a tire chips mass with sand inclusions.

As shown in Fig. 4, the increasing content of tire chips resulted in an increasing internal friction angle. Fig. 4 shows the angle of internal friction with varying tire chips content at D_r = 65%, it has been observed that with the inclusion of tire chips at a tire chips content 5%, 10%, 15% and 20% the angle of internal friction improved from 42.4° to 45.2°, 46.5°, 46.6° and 44.9° respectively i.e. an improvement in friction angle by 2.8°, 4.1°, 4.2° and 2.5°, respectively. Angle of internal friction has been improved with the addition of tire chips to the sand up to a tire chips content of 15% above which it starts decreasing. It can be said that, up to the tire chips content of 15% the frictional forces between the tire chips and sand grains reach its maximum value which improve the frictional properties of the sand. For tire chips content greater than 15%, the internal friction angle value decreases. This decrease in internal friction angle can be attributed to tire chips-sand grains interaction. Beyond the optimum value of tire chips content, the tire chips starts interacting with the tire chips rather than the sand grains and this causes little improvement in shear strength properties of sand. According to Attom (2006), in the shearing zone, tire chips are distributed and oriented randomly at the shearing surface. As shearing starts, the tire chips mixed with sands either slide or resist the shearing against cut off, which results in an increased shearing force. This resistance by tire chips against cut off increases the value of internal friction. It can be concluded that, there exist a critical value for tire chips content at which maximum improvement in shear strength and internal friction angle was obtained. These results show that soil reinforcement mechanisms take place within the tire chips–sand composite, i.e., tensile forces develop within the tire chips, leading to increased overall shear strength of the mixture. Shear among individual tire chips begins to govern the shear strength of the mixture at high tire chips contents, however,

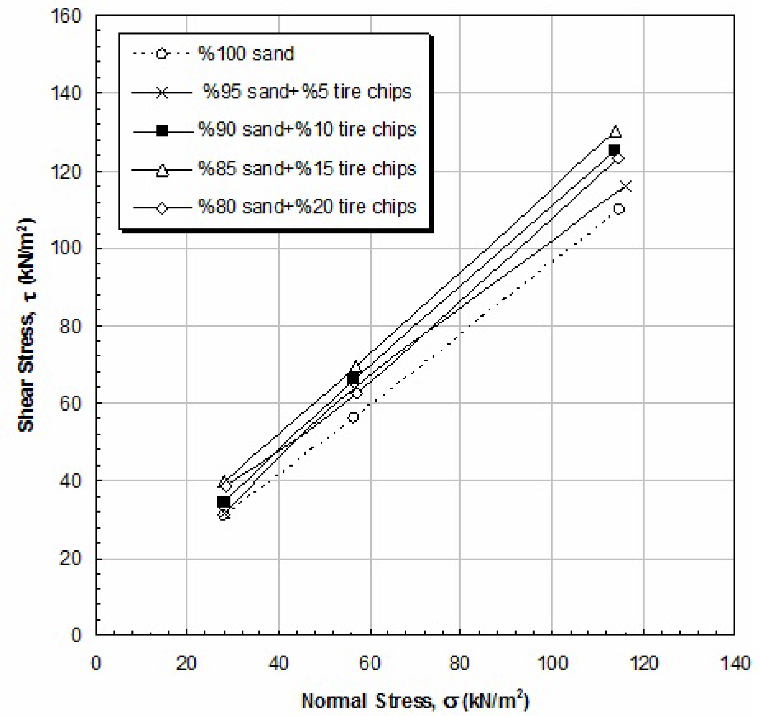

Fig. 3 Shear strength envelopes for different tire chips contents

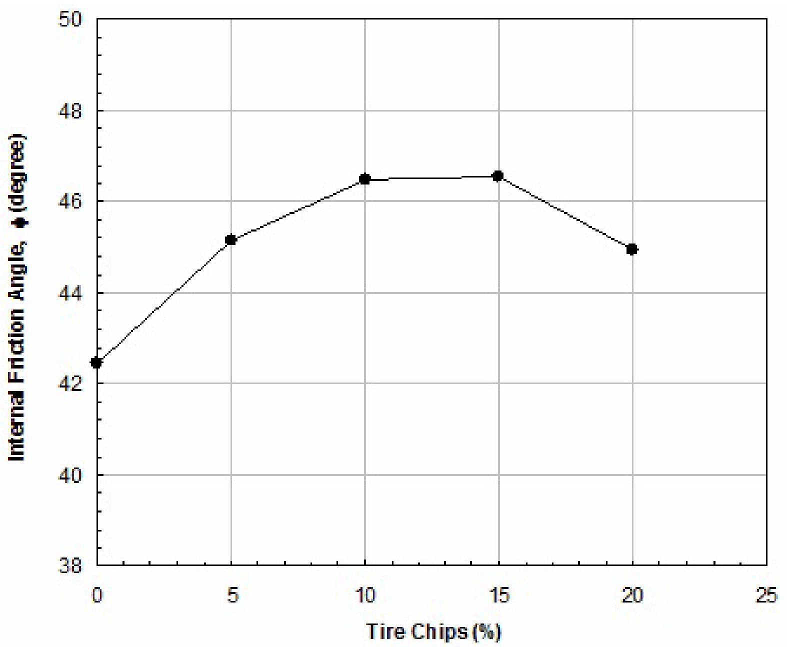

Fig. 4 Internal friction angles for different tire chips contents

leading to lower overall shear strength values. According to the strength results, the use of tire chips within sand should be considered not only as an alternative for beneficial reuse of large quantities of tires, but also as an approach to enhance the mechanical properties of backfill materials (Zornberg *et al*. 2004).

For the materials and test conditions considered in direct shear tests, the optimum tire chips content is between 10% and 15%. This represents a significantly volume of tire chips that could be beneficially reused in engineered fills.

3.2 Loading tests results

Model loading tests were carried out in a test box (Fig. 2) as described in Section 2.3, and a model strip footing of B = 70 mm width was used. Distance of the model footing to the slope crest (b) was equal to the footing width (b = 1B), the slope angle was β = 30° and relative density of reinforced sand was D_r = 65%. Effect of tire chips contents was investigated on the bearing capacity and settlement behavior of footing on sand slope. The percentages of tire chips in the loading tests were 0, 5, 10, 15, and 20% by volume similar to the direct shear test program.

In order to comparison of test results, the bearing capacity ratio (BCR) and settlement reduction factor (SRF) were used as previously described by Gudio and Christou (1988) and others

$$BCR = \frac{q_r}{q_0} \tag{1}$$

$$SRF = \frac{(s/B)_r}{(s/B)_0} \tag{2}$$

where q_r and q_0 are the ultimate bearing capacities for the reinforced and unreinforced sands, respectively and s is settlement at the corresponding ultimate bearing capacity (Yoon *et al*. 2004).

The summation of the loading test results are listed in Table 2. Fig. 5 shows load-settlement curves for unreinforced and reinforced sands obtained from performed laboratory tests. It can be seen that the curve patterns for unreinforced and reinforced sands were quite similar except for higher bearing capacities for reinforced sand and ultimate points are pronounced in the load-settlement curves. From Fig. 5, it may be clearly observed that, with increasing the contents of tire chips, ultimate bearing capacities considerably increase compared to these obtained of unreinforced sand.

Table 2 The summation of the loading test results

Tire chips content (%)	q_u (kN/m^2)	s (mm)	s/B (%)	BCR	SRF
0	56.70	3.24	4.63	1.00	1.00
5	66.32	3.44	4.91	1.17	1.06
10	106.48	5.17	7.39	1.88	1.60
15	101.75	6.70	9.57	1.80	2.07
20	87.75	5.45	7.79	1.55	1.68

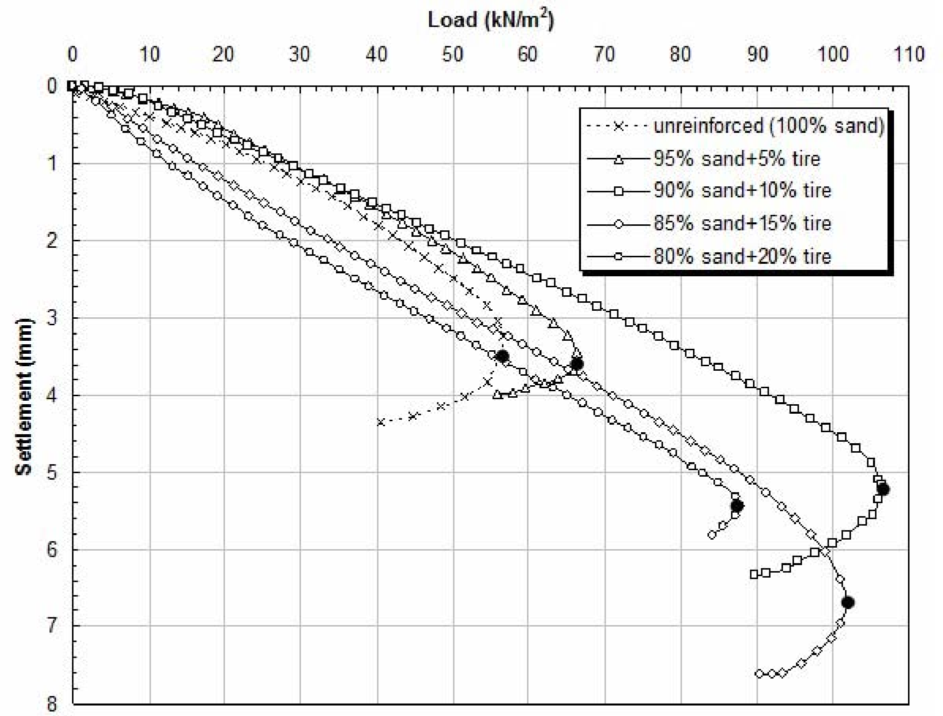

Fig. 5 Load-settlement curves for reinforced sand

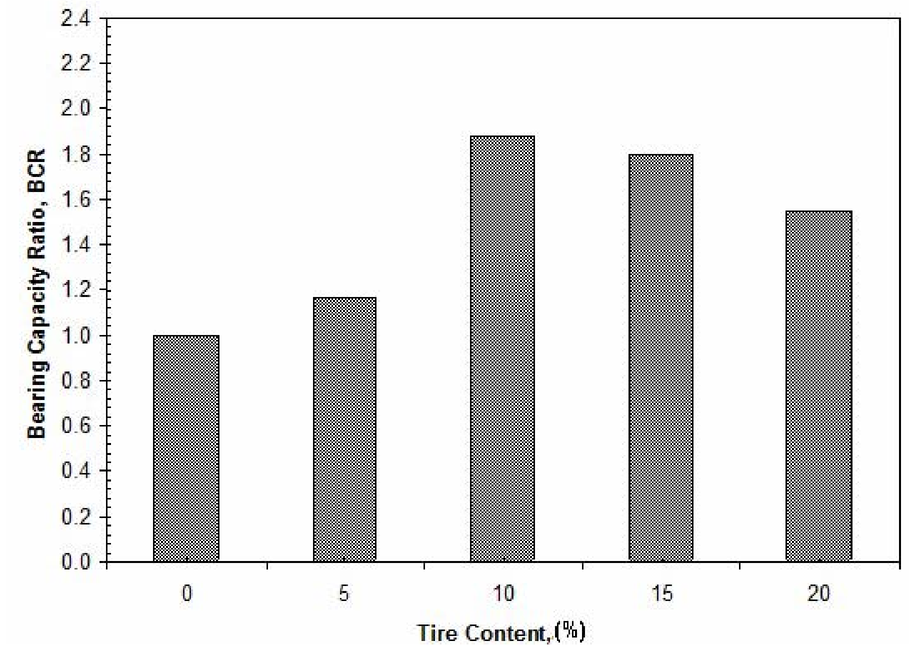

Fig. 6 Variation of *BCR* with tire content

The results indicate that, an optimum tire chips content around 10% which delivers the maximum increase in the bearing capacity. However, the addition of more tire chips after this content did not contribute to the bearing capacity improvement. The increase in bearing capacity improvement with tire chips content of 10% can be attributed to reinforcement mechanism which derived from the passive earth resistance, and interaction between the tire chips and the sand. The mobilized passive earth resistance of reinforced sand limits the spreading of slope and lateral deformations of sand particles. The mobilized tension in the reinforcement enables the tire chips to resist the imposed horizontal shear stresses built up in the soil mass beneath the loaded area and transfer them to adjacent stable layers of soils leading to a wider and deeper failure zone. According to Tafreshi and Norouzi (2012) the decrease in bearing capacity after optimum content of tire chips 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. The excess of soft tire chips particles separates soil particles and forms a soft tire chips and consequently decreases the bearing capacity of footing due to significant compressible foundation bed.

Fig. 6 shows the variations of *BCR* with tire chips content. It is clear that addition of tire chips to sand increases the bearing capacity of sand slope. The bearing capacity of sand slope increases from 56.70 to 66.32 and 106.48 kN/m^2 at tire chips contents of 5% and 10%, respectively. For tire chips content of 10% the bearing capacity increases about 88% (*BCR* = 1.88). There are 80% (*BCR* = 1.80) and 55% (*BCR* = 1.55) increase at tire chips contents of 15% and 20%, respectively.

Fig. 7 shows the variations *SRF* with tire chips content. It can be seen that, the settlements (at ultimate loads) beneath the strip footing increases 6% (*SRF* = 1.06), 60% (*SRF* = 1.60), 107% and

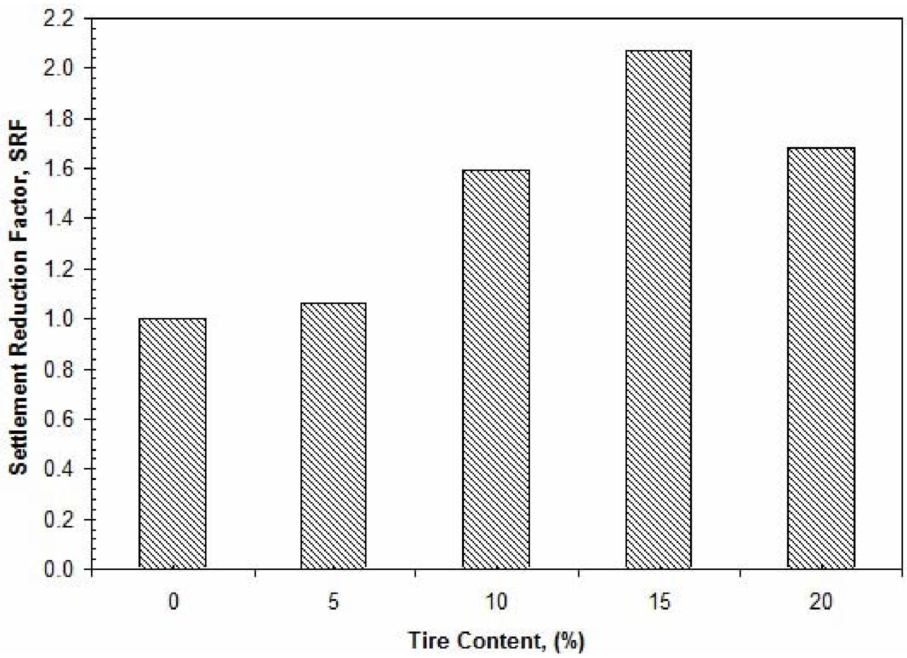

Fig. 7 Variation of *SRF* with tire content at ultimate loads

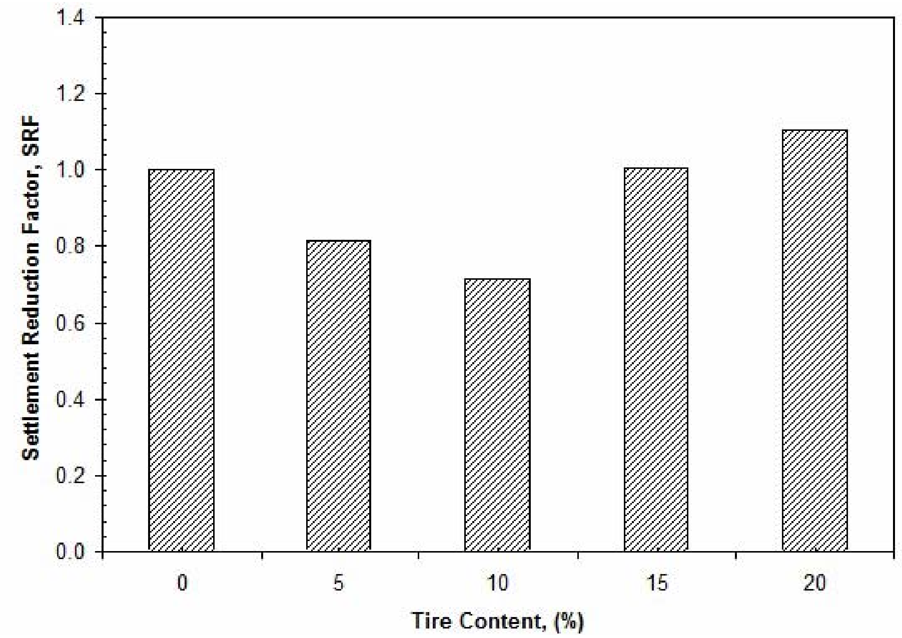

Fig. 8 Variation of *SRF* with tire content at same loading level

Table 3 Settlements at similar loading levels

Tire chips content (%)	q (kN/m^2)	s (mm)	s/B	*SRF*
0	56.70	3.24	4.63	1.00
5	57.10	2.63	3.76	0.81
10	57.13	2.31	3.30	0.71
15	57.25	3.25	4.65	1.01
20	57.10	3.58	5.11	1.11

68% for tire chips contents of 5%, 10%, 15% and 20%, respectively. The settlements were 3.44 m, 5.17 mm, 6.70 mm and 5.45 mm for tire chips contents of 5%, 10%, 15% and 20%, respectively, while it was 3.24 mm for unreinforced case. It can be said that, the settlement behavior tends to be influenced by the high deformability of tire chips material and hence the settlement increases at ultimate loads.

However, it can be seen from Table 3 and Fig. 8 that, at the similar loading level, the settlement of strip footing on sand-tire chips mixture was about 30% less than in the case of pure sand up to percentage of 10% tire chips. The settlements (at ultimate load for unreinforced case) beneath the strip footing reduces 19% (*SRF* = 0.81) and 29% (*SRF* = 0.71) for tire chips contents of 5% and 10%, respectively. For tire chips contents of 15% and 20%, the settlement of the footing increases slightly. The settlements were 3.25 mm and 3.58 mm for tire chips contents of 15% and 20% respectively, while it was 3.24 mm for unreinforced case.

4. Limitations

In this study, the model tests were conducted on a small scale model footing, while the used sand particles and tire chips were the same dimensions as in the prototype. Therefore, model footing or the soil, may not play the same role as in the prototype and it might cause some influence on the model test results. Despite the mentioned disadvantages that scaling effects due to using prototype sand and tire chips will occur in model tests, the study indicated the benefits can be obtained when using tire chips to reinforce sand slopes. This study can be evaluated as a useful basis for further research in which the results of this study can be of support with full-scale loading tests or centrifugal model test studies.

5. Conclusions

In this study a series of direct shear and model plate load tests have been carried out on reinforced sand slope. Tire chips were used as reinforcement elements. First, the effect of tire chips content on the shear strength behavior of tire chips–sand mixtures was evaluated. Then, the bearing capacity and the settlement behavior of strip footings supported on the tire chips reinforced and unreinforced slope were investigated. Based on the test results, the following conclusions can be drawn:

- The results have demonstrated the benefits of recycling of tire chips to reinforce a cohesionless soil. It can be concluded that tire chips mixed in sand can result in greater strength.
- The increase in the percent of tire chips increases the angle of internal friction of the sand. In direct shear tests, the optimum tire chips content is between 10% and 15%. Tire chips addition to sand increases the internal friction angle from 42.44° to 46.5° at 10% and 46.6° at 15% content of tire chips, respectively. Any further increase in the tire chips content caused a decrease in strength.
- A significant improvement in footing performance resting on a sand slope can be obtained by using tire chips. From the results of model loading tests, for the given materials and test conditions, the bearing capacity of footing increases with increase in the tire chips content up to the optimum value, after which the bearing pressure decreases. So, the results suggest the re-use of tire chips mixed with soil as reinforcing elements beneath the footing.
- The optimum percentages of tire chips are measured around 10% of the total volume of tire chips-sand mixture. This leads to the maximum improvement in bearing capacity of footing. At optimum tire chips content, the ultimate bearing capacity value can be improved by up to approximately 1.9 times those of the unreinforced slope.
- The settlement behavior tends to be influenced by the high deformability of tire chips material and hence the settlement increases at ultimate loads. However, at the same loading level, the settlement of strip footing on sand-tire chips mixture up to percentage of 10% tire chips was about 30% less than in the case of pure sand.

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