INVESTIGATION ON BEHAVIOUR OF SOILS REINFORCED WITH SHREDDED WASTE TYRES

V. Vinot
Post-graduate Student, Department of Civil Engg., Indian Institute of Technology, Guwahati–781039, India.
E-mail: v.vinot@iitg.ernet.in

Baleshwar Singh
Associate Professor, Department of Civil Engg., Indian Institute of Technology, Guwahati–781039, India.
E-mail: baleshwar@iitg.ernet.in

ABSTRACT: Post-consumer tyres have become a growing disposal problem caused by increasing number of vehicles on the roads. To this aim, the present study is to investigate the effect of shredded waste tyres on strength behaviour of locally available soils. To assess the behaviour of reinforced soils, proctor and vibratory compaction, unconfined compression, and direct shear tests were conducted. Test results show that due to the addition of shredded tyres to silty soil, both the peak and residual compressive strength increase along with change of behaviour to a ductile one. In case of sand, the shredded tyre inclusion with varying shred size increases both the cohesion intercept and the shear strength. Further, the dilatancy of sand gets gradually suppressed. With increase in shred content, the dry density of the soil-tyre mixes decreases. Thus, the reuse of waste tyres in reinforcing soil can offer an attractive solution in reducing tyre stockpiles.

1. INTRODUCTION

Waste tyre generation is always on the increasing trend everywhere in the world. The growing volume of waste tyres has prompted interest in developing new ways to reuse them. Rubber tyres do not decompose easily. While detrimental from an environmental perspective, this property may help in using such a material for some engineering applications. Waste tyre utilization should minimize environmental impact and maximize conservation of natural resources. Waste tyres have been used for reinforcing soft soil in road construction (Bosscher et al. 1997), for stabilizing slopes (Huat et al. 2008), for backfilling in retaining structures (Lee et al. 1999). In fact, engineers studying the physical properties of soil-shred mixes have concluded that this mix can be used in many engineering projects. In view of the above, the objective of study is to investigate the influence of shredded waste tyres or simply shreds on the strength behaviour of locally available soils.

2. PREVIOUS STUDIES

Inclusion of shredded tyres increases the shear resistance of sand alone (Foese et al. 1996, Zornberg et al. 2004). Addition of shredded tyres to sand influences significantly the variation of cohesion intercept with marginal variation in angle of internal friction (Ghazavi 2004, Rao & Dutta 2006). Tatlisoz et al. 1997) conducted direct shear tests on silty soil reinforced with tyre shreds. They concluded that silty soils are as suitable as sands for use in soil-shred mixtures. When shredded are tyres mixed with soil, it reduces the compressibility of pure shredded tyre fills (Tatlisoz et al. 1997). Tyre shreds placed below the water table appear to have a negligible offsite effect on water quality (Humphrey & Katz 2001).

3. TESTED MATERIALS

The experimental programme in this study was conducted with a silty soil and a sandy soil. They were collected from within the Institute premises and from a nearby bank of the Brahmaputra River respectively. The soils were characterized by means of laboratory tests as per the provisions of Indian Standard codes.

The silty soil and sand can be designated as ML and SP as per the Unified Soil Classification Systems (USCS). The respective specific gravity values are 2.51 and 2.71. Their grain size distribution curves are shown in Figure 1. Scrap tyres were shredded into three different sizes (10 mm × 10 mm, 10 mm × 20 mm, 10 mm × 30 mm) for use with the sand and < 3 mm size for use with the silty soil. The larger shreds had thickness ranging from 5 to 7 mm and also contained some nylon fibres. The specific gravity of the tyre shreds ranges from 0.86 to 1.19 depending on the nylon fibre content.
4. TESTS CONDUCTED

4.1 Compaction Tests

In the case of silty soil and mixtures, the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) were determined using standard proctor tests. The tests were carried out as per Indian Standards (IS: 2720 Part 7 – 1980).

In the case of sand and mixtures, maximum and minimum dry density were determined using vibratory tests by varying shred content of 0 to 100% in steps of 10%. The tests were carried out as per Indian Standards (IS: 2720 Part 14 – 1983).

4.2 Unconfined Compression Tests

Unconfined Compression (UC) tests were performed as per Indian Standards (IS: 4332 Part 5 – 1970) on all specimens of 38mm \( \varnothing \) and 76 mm height using a strain rate of 1.25 mm/min. Corrections to the cross-sectional area were applied prior to calculating the compressive stress on the specimen. Each specimen was loaded until peak stress was obtained, or until an axial strain of 10% was obtained. The specimens were cured for different curing periods (3, 7, and 14 days). Three specimens for each curing period were prepared in order to provide an indication of repeatability. Many factors may affect the unconfined compressive strength of a reinforced soil, but the more important factors are the shred content and curing period.

4.3 Direct Shear Tests

A large direct shear box consisting of two halves of size 30 × 30 × 15 cm each was used to investigate the shear strength of sand and sand-shred mixtures. The reinforced specimens contained varying shred contents of 10%, 20%, 30%, 40% and 50% shreds by total dry weight as well as varying aspect ratio (shred length/shred width ratio) of 1, 2, and 3. For preparing the specimens, quantity calculations were first made to determine the amount of sand and shreds for each mixture and then poured in a container for uniform mixing manually. The mixed materials were steadily poured into the shear box in three layers. Care was taken to avoid any segregation of the shreds.

For compaction purpose of every layer, a rectangular wooden plate of size slightly less than that of the shear box was placed at the top of each layer. A mass of 0.2 kg was dropped from a height of 10 cm on the plate three times for each layer. Care was taken to deliver equal hammer energy all over the plate and finally to the sample. A similar compaction procedure was adopted by Ghazavī (2004) to make slightly compacted samples. The tests were carried out as per Indian Standards (IS: 2720 Part 13). Five different normal stresses of 25, 50, 75, 100, and 125 kN/m² were used. The shearing rate was kept at 0.5 mm/min for all tests, close to shear rate used by others, for example Tatlisoz et al. (1997). The tests were continued until the shear stress became essentially constant or until a maximum shear deformation of 25 mm was reached. Prior to calculating the shear stresses on the specimens, area corrections were applied. When no peak stress was observed, the shear stress at 25 mm displacement was taken as the ultimate shear stress.

5. TEST RESULTS AND DISCUSSION

5.1 Compaction Behaviour of Reinforced Soils

For silty soil and silt-shred mixtures, the standard proctor tests were conducted to investigate the compaction behaviour. The results are presented in Figure 2. Compaction curves for reinforced soil are similar to that of unreinforced soil. Addition of shredded tyres has little influence on the Optimum Moisture Content (OMC). The Maximum Dry Density (MDD) of the mixes decreases with increasing shred content as expected. The decrease in density is due to the lighter unit weight of the shreds.

![Compaction Curves for Silty Soil Reinforced with and Without Shreds](image)

Fig. 2: Compaction Curves for Silty Soil Reinforced with and Without Shreds

For sand alone and sand-shred mixtures, the vibratory compaction tests were conducted to investigate the compaction behaviour. The results are presented in Figure 3. It is observed that the reduction in dry density very much affected by shred content.

![Variation of Maximum Dry Density with Shred Content](image)

Fig. 3: Variation of Maximum Dry Density with Shred Content
5.2 Unconfined Compression Behaviour of Reinforced Silty Soil

The stress–strain curves of both un-reinforced and reinforced shred-soil specimens are shown in Figure 4. The results indicate that the stress–strain behaviour is markedly affected by the shred inclusions. It shows that the addition of shredded tyres improves the peak as well as residual compressive strength of silty soil. The inclusion of shreds to a soil medium leads to replacement of a portion of the soil by elastic material. As a result, the soil mix becomes softer with the reinforced specimens having change of behaviour to a ductile one.

From Figure 5, it is observed that the increase of shred content improves the UCS value of soil linearly. At constant shred content, the increase in age causes non-uniform increase in unconfined compressive strength. The strength is noted to be predominant at 7 days.

5.3 Shear Strength Behaviour of Reinforced Sand

Direct shear tests were performed on sand alone and sand-shredded tyre mixtures. Typical variation of shear stress-displacement curves at a normal stress of 100 kPa for sand with shred inclusion of 10 mm × 20 mm size are presented in Figure 6, along with those of sand alone. For the sand alone, the shear stress initially increases and then levels off at a horizontal displacement of 9 to 10 mm. In contrast, the shear stress for the sand-shred mixtures continues to increase with horizontal displacement. Thus, greater displacements are required to mobilize the ultimate shear strength of sand-shred mixtures than for sand alone. Similar findings have been reported by Foose et al. (1996) for sand-tyre chip mixtures.

Typical variation of volume change curves at a normal stress of 50 kPa for sand with shred inclusion of 10 mm × 10 mm size are illustrated in Figure 7, along with those of sand alone. At the same normal stress applied on the specimens, the presence of shredded tyres in the shear plane limits the amount of vertical deformation or dilation in sand. Similar findings were observed by Lee et al. (1999).
Typical variations of shear stress versus normal stress for sand and mixtures with shred size of 10 mm × 30 mm are shown in Figure 8. Comparable trends were observed for other shred sizes. The failure envelopes are almost linear for reinforced specimens up to 30% shred content similar to that of sand, and have cohesive intercept varying with shred content due to interaction between shred-shred, sand-sand, and shred-sand. The friction angle increases by 2° to 6° due to addition of shreds compared to the 36.65° angle for sand alone. The cohesion intercepts increases linearly with shred content for all shred sizes.

6. CONCLUSIONS

The study has demonstrated the feasibility of using shredded waste tyres to reinforce soils. From compaction and unconfined compression tests conducted on silt-shred mixtures, it can be concluded that the randomly distributed shreds in a compacted fine-grained soil can result in greater strength and ductility. On the other hand, the direct shear tests conducted on sand-shred mixtures revealed that the inclusion of shredded tyres in the sand leads to increase in shear resistance at higher displacement although the magnitude and nature of this increase was affected by shred content and normal stress level. Thus, the incorporation of shredded tyres in both the soil types showed some useful improvement in the strength behaviour. It can be stated that the use of shredded waste tyres in geotechnical applications along with locally available soils will have an overall net positive impact on the environment since large quantities can be consumed.

REFERENCES


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