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WASTE TIRE SHREDS AS SOIL REINFORCEMENT

Nader Shariatmadari [a], Meharn Karimpour-Fard [b*], Masoud Roustazadeh [c]

[a] Iran University of Science and Technology, Tehran, Iran, shariatmadari@iust.ac.ir
[b] Iran University of Science and Technology, Tehran, Iran, karimpour_mehran@iust.ac.ir
[c] Iran University of Science and Technology, Tehran, Iran, m_roustazadeh@civileng.iust.ac.ir

[*] Corresponding member

ABSTRACT

The volume of scrap tires which are undesired urban waste is increasing every year. Shredded tires or their mixture with soil can be a proper alternative as a lightweight material in many geotechnical applications. This material not only addressed growing environmental concerns like fire hazards but also solve geotechnical problems associated with low soil shear strength. Besides high weight of soil materials when were used in backfills, has a serious impact on the dynamic stability of soil construction because of the higher applied dynamic loads. In a laboratory research, using a large direct shear apparatus with dimension 30.5*30.5*15 (cm), the mechanical behavior of the tire shred & soil mixtures have been evaluated and the results were compared with alone soil. To overcome the problems due to scale effect of tire Shreds 3 group of tire shreds with dimensions 2*2, 2*4 and 4*4 (all dimension in cm) were chosen. The results of this research showed that the tire shreds & soil mixture has higher strength in comparison with alone soil and for each specified dimension of tire shreds, there is an optimum value (percent by volume) that represent a maximum shear strength. Increasing the shear strength of the mixtures with increasing the dimension of tire shreds was another result of this research.

KEYWORDS: tire shred, sand, tire shred-sand mixture, mechanical behavior, shear strength

INTRODUCTION

The mechanical behavior of soils had been an attractive field for geotechnical researchers. Evaluation of this behavior under various conditions like loading, value of moisture content, density as well as presence of reinforcement elements had been the subject of a large number of academic researches. In this respect mechanical behavior of improved soil has been of great concern since many years ago. The lack of proper mechanical properties of soft or problematic soils pushes the researchers to find a way to overcome these deficiencies. A traditional solution for this improvement is adding some sound element to the soil. These materials themselves need to have sufficient strength and durability.

Using non-conventional materials like scarp tires had been one of the most interesting fields of soil improvement researches. Since waste tires don't go back to the environment cycle, geotechnical engineers should make good ideas to reuse them. The use of waste tires in civil engineering applications is increasing such that it is anticipated that In the future, 65 percent of waste tires will be used in civil engineering projects.

In recent years because of bulky shape and large needed space, deposing of scarp tires in sanitary landfill has been banned and because of this reason a large number of waste tire are entering to the environment which has been created a critical situation. The number of waste tires In the United States averagely accounts for about 270 million. In Canada, this figure is about 28 million. Only 30% of the above waste tires are deposited in landfills (CCME [1]).

Waste tires are used in various applications in civil engineering:, for instance, tor reinforce soft soil and road construction (Bosscher et al. [2]; Nightingale et al, [3]), in earthwork projects and stabilizing (Poh and Brorns [4] ; Garga and O'Shaughnessy [5, 6 and 7]) and as lightweight material for backfilling in retaining structures (Lee, et al, [8], Sumanarathna et al.[9]; Tweedie et al. [10]; Allman and Simundic [11] and etc.).

Several researches have been done on the mechanical behavior of tire shred-sand mixture which in chronological order are as follows:

Ahmed [12] using large-scale triaxial apparatus 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. Benson and Khire [13] evaluated the shear strength of mixtures of sand and high-density polyethylene (HDPE) strips with different aspect ratios using large-scale direct shear tests and concluded that HDPE strips increased the peak shear strength and residual shear strength of the composite material.

Edil and Bosscher [14] using large-scale direct shear tests concluded that tire shred inclusions improve the shear strength of tire shred – sand mixtures, especially for low and intermediate confining pressures. Lee et al. [8] performed triaxial tests using pure tire shreds and tire shred – sand mixtures to investigate the effect of varying confining pressures. Pure tire shred specimens showed an approximately linear stress–strain response for a wide range of confining pressures, and tire shred – sand specimens showed a response intermediate between those of pure sand and pure tire shreds.

Foose et al. [15] performed large-scale direct shear tests on tire shred – sand mixtures and concluded that shear strength was significantly affected by the normal stress, tire shred content, and sand matrix unit weight. Youwai & Bergado [16] conducted a series of triaxial tests on shredded tires and sand mixtures to evaluation of their mechanical behavior. They represented a constitutive model and a critical state frame work for these materials.
Zornberg et al. [17] using large triaxial apparatus showed that For a given tire shred content, increasing the tire shred aspect ratio led to increasing overall shear strength. They also stated that the shear strength improvement induced by tire shred inclusions was found to be sensitive to the applied confining pressure, with larger shear strength gains obtained under comparatively low confinement. Ghazavi & Amel Sakhi [18, 19] stated that there is an optimized tire shreds on shear strength parameter of sands which depends on the tires shreds dimensions.

Although past studies have shown evidence of the beneficial effect of tire shred inclusions when mixed with soil, quantification of such improvement, assessment of the effect of soil density, and optimization of tire shred content deserve further study. In this research using a large direct shear box apparatus, the mechanical behavior of tire shred-sand mixture was evaluated and the effect of size, percentage of shredded tire and etc. was estimated.

MATERIALS

Sand

The sand which was used in this research was fine silty silicate sand, named Mahan sand. The result of this soil's sieve analysis is presented in Fig. 1-A. A complementary hydrometery test showed that in addition of 85% sand, this soil includes 12% silt and 3% clay.

Tire Shreds

The used tire shreds in this research had an average shell thickness of 3 mm. ASTM specification for evaluation of shear strength of geomaterials by direct shear box apparatus, D3080-98; eliminate the maximum dimensions of materials to $1/5 \sim 1/6$ of box dimension. This rule has been presented to overcome the problems due to scale effect of particles of specimens in laboratory element tests. This limitation was the main reason to choose the maximum shred size of 4 cm (Fig. 1-B).

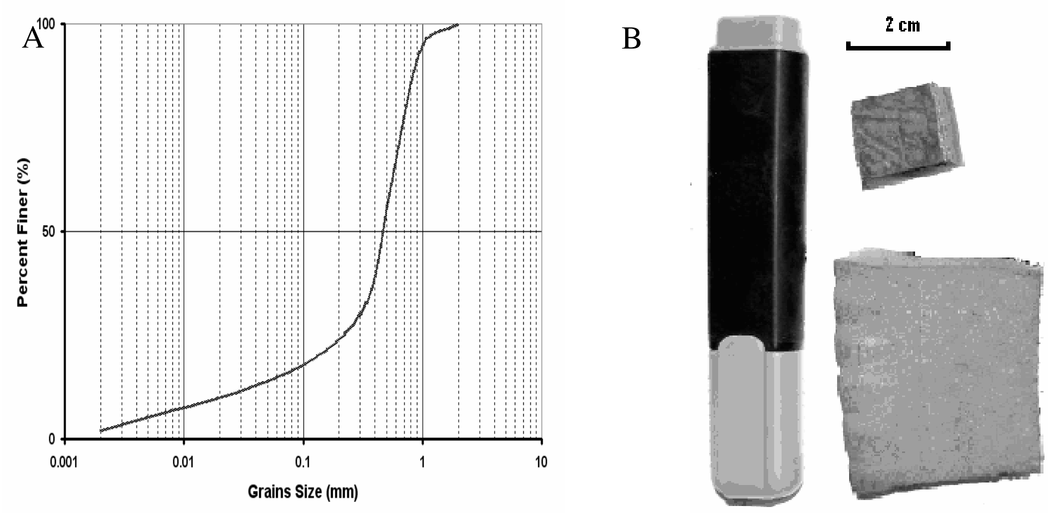

FIGURE 1- A: GRADING GRAPH OF USED SOIL, B: A VIEW OF THE USED TIRE SHREDS

TESTING DEVICE, PROCEDURE AND PROGRAMMING

A series of large scale direct shear test has been conducted to evaluate the mechanical behavior of tire shred-sand mixture. The used direct shear apparatus had a box with dimension of 30.5*30.5*15 (all dimensions in cm) (Fig. 2). Using a dial gage with a traveling course up to 25 mm, during applying load, the shear displacement of specimens were measured. It is worthy to note that the procedure of applying shear stress to the specimens was stress control

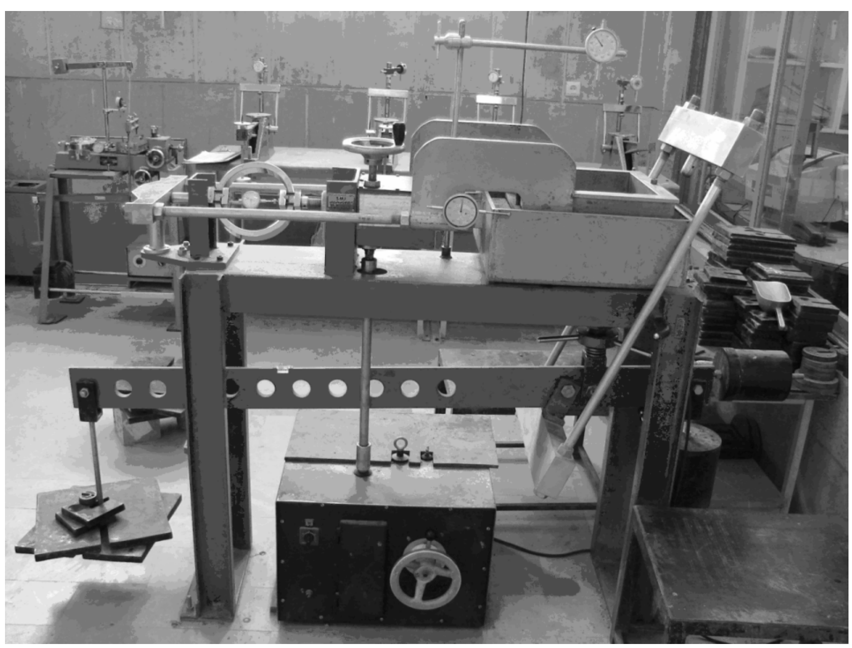

FIGURE 2- A SIDE VIEW OF THEUSED LARGE SCALE DIRECT SHEAR APPARATUS

At first step to reach a base to evaluate of the effect of adding tire shreds to sand, the mechanical behavior of alone sand were evaluated and then various amount (percent by volume) of tire shreds were added to sand. To estimate the density of tire shred-sand mixture, the relationships presented by Foose et al. [15] was used. Also it should be mentioned that the compaction efforts for each series of tests including alone sand and tire shred-sand mixture with various amount additives was same

RESULTS AND DISCUSSIONS

A distinct result of this research was the effect of presence of shredded tires on the mechanical behavior of specimens which shows an increase in the shear strength of mixtures. In comparison to the base materials which was alone soil and in a loose state, adding only 15% of shredded tire (percent by volume) increases the shear strength of mixture up to 40% and 45% percent for 2*2 (cm) and 4*4 (cm) shredded tires respectively (Fig 3).

As illustrated in Fig.3 the difference between shear response of mixed specimens in comparison of alone soil, increase with shear displacement that is a distinct specification of reinforced soils.

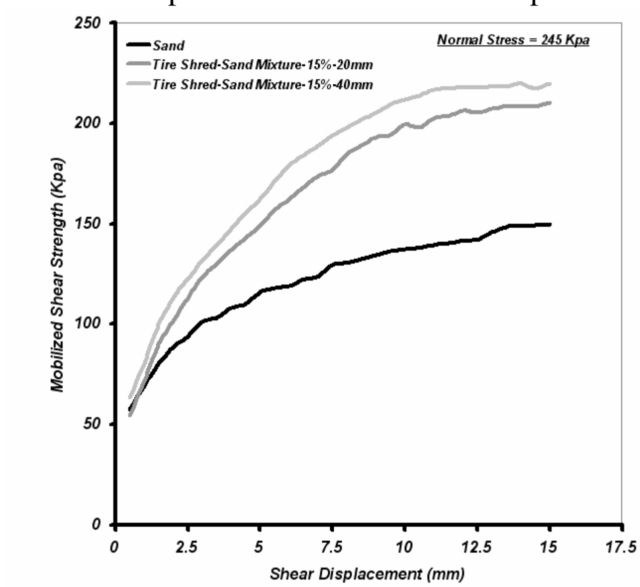

FIGURE 3- EFFECT OF THE SIZE OF TIRE SHREDS ON THE MECHANICAL BEHAVIOIUR OF MIXTURES

It should be mentioned that because of random orientation of shredded tires particles in the specimens, the range of strength increase was different which indicate on the strength anisotropy of tire shred-Sand Mixtures (Fig .4)

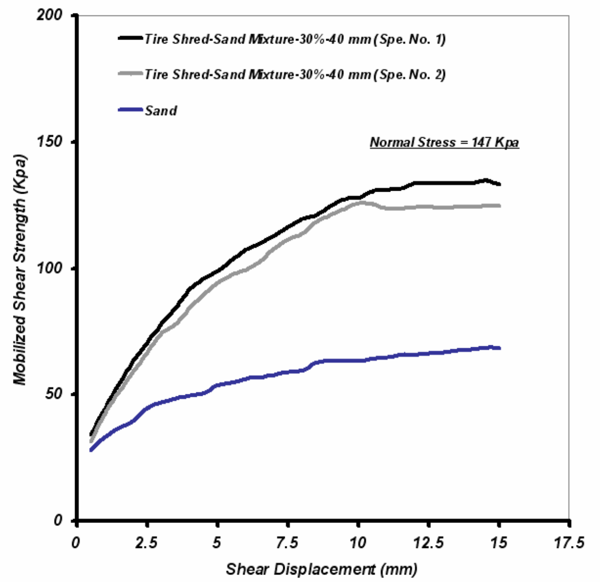

FIGURE 4- EFFECT OF THE TIRE SHREDS ORIENTATION OF THE MECHANICAL BEHAVIOUR AND STRESS ANISTROPY OF MIXTURES

The results of this research showed that there is an optimum value for added tire shreds to reach a maximum shear strength which is a function of tire shred dimension. In Fig 6 a typical results of this research has been represented which indicates on the presence of an optimum values for added tire shreds to the mixture. As could be seen in this graph for tire shreds with dimension of 4*4 cm and for 196 Kpa normal stress there is an optimum value between 30% and 50% added tire shred. It is worthy to note that only except in limited cases, no peak in the stress-strain curve was observed and because of this reason a displacement base failure criterion was chosen for interpretation of test results by Mohr-Coulomb constitutive model.

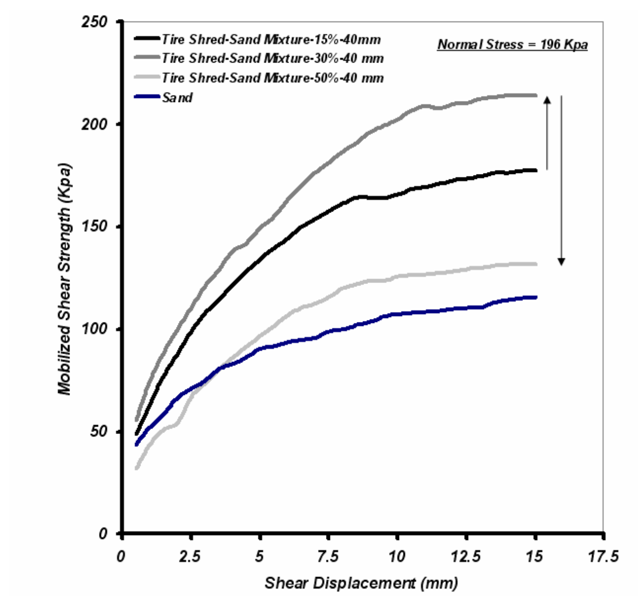

FIGURE 5- THE EVIDENCE OF EXISTENCE OF AN OPTIMUM VALUE OF TIRE SHREDS

In Fig. 6, a typical result of these interpretations for tire shreds with dimension of 2*2 cm is presented. It should be mentioned because of short traveling course of used dial gage in tests, the failure criterion was chosen 15 mm shear displacement and it is possible that the results of the interpretation of direct shear test based on Mohr-Coulomb constitutive model been under estimate. In this figure it could be seen that optimum value for internal friction angle and cohesion intercept are different but because of this reason that after 20% the value of internal friction angle is almost constant therefore a value equal to 25% could be an optimum value for tire shreds to reach the maximum mobilized shear strength.

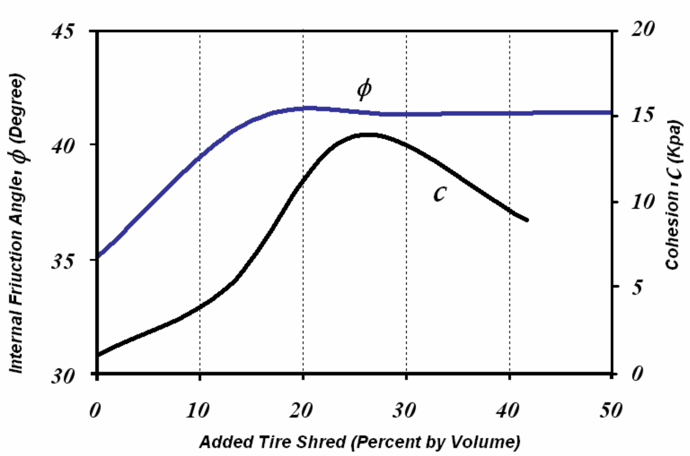

FIGURE 6- The ENVELOPE GRAPH OF MOHR-COULOMB PARAMETERS FOR TIRE SHREDS WITH DIMENSION OF 2*2 cm

CONCLUSION

In recent year the number of scrap tires has increased progressively and because of this reason civil engineers especially geotechnical engineers tend to use these materials in earth constructions. For this purpose at first step the mechanical behavior of mixtures of soil and scrap tires in the form of whole, shreds and chips should be evaluated. Several research until now has been mad on the mechanical behavior of tire shred-sand mixture that current research is one of them.

In this research using a large direct shear apparatus, the mechanical behavior of these mixtures with various volume percent of shredded tires and as well as different dimension were evaluated.

The results of this research showed that there is no doubt that adding shredded tires to the soil could increase shear strength of mixtures but the value of this increase is a function of added volume percent of shredded tires and their dimension.

This research showed that for each size of tire shreds there is an optimum value of added shreds which represent highest shear strength. It was also shown that increasing the tire shred dimension increase the shear strength of mixtures.

REFERENCE

1. Council of Ministers for The Environment (CCME). Harmonized economic instruments for used tires. Final Rep. Prepared for the Canadian Council of Ministers/or the Environment, Apogee Ref. 363 CCME, No. CCME-SPC-EITG-92E., Canada, 1994.

2. Bosscher, P.J., Edil, T.B., and Kuraoka, S. Design of highway embankments using tire chips. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 1997 123(4): 295–304.
3. Nightingale, D. E. B., and Green, W. P. An unsolved riddle: Tire chips, two roadbeds, and spontaneous reactions. Testing Soil Mixed with Waste or Recycled Materials, ASTM STP 1275, M. A. Wasemiller, K. B. Hoddinott, Eds. 1997 , pp. 265-285.
4. Poh, P. S, H., and Broms, B. B. Slope stabilization using old rubber tires and geotextiles. Journal of Performance of Constructed Facilities, 1995, Vol. 9, No. I, pp. 76-80
5. Garga, V.K., and O'Shaughnessy, V. Tire-reinforced earthfill. Part 1: Construction of a test fill, performance, and retaining wall design. Canadian Geotechnical Journal, 2000, 37: 75–96.
6. O'Shaughnessy, V., and Garga, V.K. Tire-reinforced earthfill. Part 2: Pull-out behaviour and reinforced slope design. Canadian Geotechnical Journal, 2000, 37: 97–116.
7. O'Shaughnessy, V., and Garga, V.K. Tire-reinforced earthfill. Part 3: Environmental assessment. Canadian Geotechnical Journal, 2000, 37: 117–131.
8. Lee, J. H., Salgado, R., Bernal, A., and Lovell, C.W. Shredded Tires and Rubber–Sand as Lightweight Backfill, Journal of Geotechnical and Geoenviromental Engineering, ASCE, 1999, Vol. 125, No. 2, pp. 132–141.
9. Sumanarathna, 1. H. D., Mallawarctohie, D. P., and Kulathilaka, S. A. S. Stabilization of slopes by anchored type retaining structures." Proceedings 14th international Conference of Soil Mechanics and Foundation Engineering, New Delhi, India, 1997, pp. 1261-1264.
10. Tweedie J.J, Humphrey, D.N., and Sanford, T.C. Tire-shreds as lightweight retaining wall backfill." Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 1998, 124(11), pp. 1061-1070.
11. Allman, M. A. and Simundic, G. Testing of a retaining wall constructed of waste tyres. Proceedings Third International Congress on Environmental Geotechnics, 1998, Vol. 2, pp. 655-660, Lisboa, Portugal.
12. Ahmed, I. Laboratory study on properties of rubber-soils. Ph.D. thesis, School of Civil Engineering, Purdue University, 1997, West Lafayette, Ind.
13. Benson, C.H., and Khire, M.V. Reinforcing sand with strips of reclaimed high-density polyethylene. Journal of Geotechnical Engineering, ASCE, 1994, 120(5): 838–855
14. Edil, T.B., and Bosscher, P.J. Engineering properties of tire chips and soil mixtures. ASTM Geotechnical Testing Journal, 1994, 17(4): 453–464.
15. Foose, J., Benson, H., and Bosscher, J. Sand Reinforced with Shredded Waste Tires. Journal of Geotechnical Engineering, ASCE, 1996, Vol. 122, No. 9, pp. 760–767.
16. Sompote Youwai and Dennes T. Bergado. Strength and deformation characteristics of shredded rubber tire – sand mixtures, Canadian Geotechnical Journal, 2003, 40: 254–264.
17. Jorge G. Zornberg, Alexandre R. Cabral, and Chardphoom Viratjandr. Behaviour of tire shred – sand mixtures, Canadian Geotechnical Journal, 2004, 41: 227–241.
18. Ghazavi, M., and Amel-Sakhi, M. Influence of optimized tire shreds on shear strength parameters of sand. International Journal of Geomechanics, ASCE, 2005, Vol. 5, No. 1, March, pp. 58-65.
19. Ghazavi, M., and Amel-Sakhi, M. Optimization of aspect ratio of waste tire shreds in sand-shred mixtures using CBR tests. Geotechnical Testing Journal, 2005, Vol. 28, No. 6, pp. 564-569.