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# A Study of the Effect of Shredded Tire Size on the Mechanical Behavior of Sand and Shredded Tire Mixtures Using Direct Shear Test

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## 1- Introduction

In the recent times of industrialization era, the consumption of rubber is growing. For instance, almost 26 million tons of rings of vehicle cars have been spoiled in the year 2003 in Europe. The same problem exists in Iran. It is expected that in the next 10 years, about 930 thousand tons of consumed tires would be produced. So far, attempts were made to use these materials for various purposes in order to get rid of the environmental problems of burying these worn out tires. Almost half of the materials are used as fuel for burning furnaces of cement production facilities. Other applications are for pavement covers or seismic elastomer absorbers. In the domain of civil engineering problems, these materials have been used in the form of shred (powders) or bigger sizes named as rubber chips with a mixture of soil as for the backfill of retaining walls. The soil-rubber mixture facilitates the role of water drainage from the back of the retaining walls. In geotechnical engineering practice, the main question regards the mechanical behavior of these materials including the shear strength and deformational properties.

In the literature review, there are some works that studied different types of rubber chips. The works were mostly focused on the shear strength parameters and the deformational properties were paid less attention. In the laboratory, the mixtures have been tested with the help of triaxial compression as well as direct shear test apparatus.

## 2- The aim of this study

In this paper, the effect of grain size of shredded tire on the mechanical behavior of the sand-shredded tire mixture is studied experimentally. To this aim, one type of sand as well as three different sizes of shredded rubbers were considered for the materials. In order to study the mechanical behavior, the direct shear test apparatus was implemented for the test programs. The effect of the admixture of the rubber shreds was investigated by virtue of the variations of friction angle as well as the stiffness of the mixtures.

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## 3- Methodology

The study is based on experimental tests in the laboratory. The mixture of sand-rubber shred with different weight percentage values were mixed and the samples were sheared by Direct Shear Test (DST) apparatus. Three different sizes of shredded tires (fine, medium-coarse and coarse) were added to the sand with different percentages. For all types of rubber shreds, the weight percentage of zero, 0, 40, 70, 100 were used.

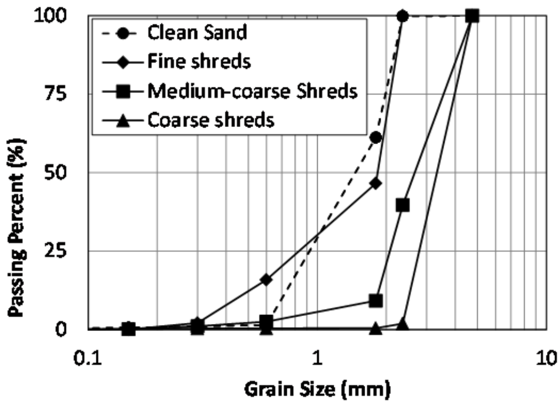


**Fig. 1. Grain size distribution of the materials**

The size and distribution of sand and the shredded tires are depicted in Fig. 1. The specific gravity ($G_s$) of the materials was determined according to ASTM D854-02. In all series of the tests, the mixtures of the soil-rubber were tested at the relative density of 75±5%. The maximum and minimum densities were measured according to ASTM D4253-93 and ASTM D4254-93, respectively.

The dimension of the direct shear box was 100*100 mm and the rate of displacement was considered to be 2 mm/min. It is also noted that the effect of displacement rate on the mechanical behavior was examined by using three different rates of 0.2, one and two m/min and it was found that it has no influence on the behavior. All the samples were tested in dry conditions. Each test includes two stages. At first, the samples were loaded with vertical loads that impose vertical stresses of 25, 50, and 100 kPa and then, the samples were loaded by lateral movement which causes the sample to be sheared. According to Fig. 2, the vertical loading was imposed with different steps in order to see the compressibility behavior of the mixtures. Totally, 45 direct shear tests were performed.

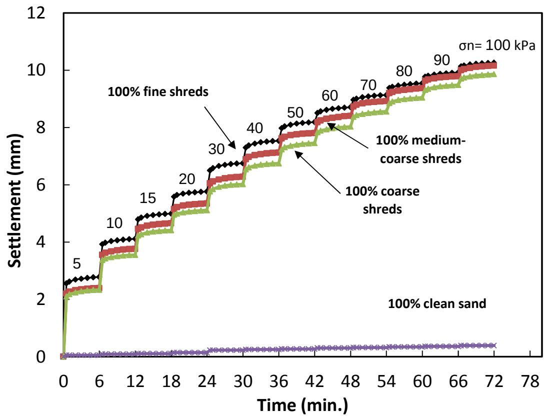


**Fig. 2. Variation of settlement of the samples with time for different levels of vertical loading**

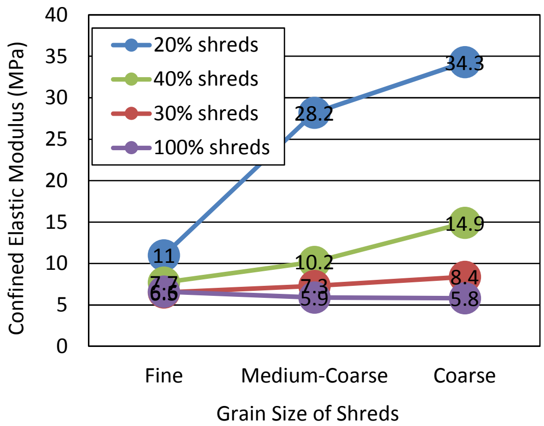


**Fig. 3. Confined elastic modulus of the mixtures**

## 4- Concluding Remarks

Based on the experimental results, the following conclusions were drawn:

- The rate of loading (displacement) did not influence the mechanical behavior of sand and sand-rubber mixtures.
- According to the first stage of loading (vertical loading), the compressibility of the shredded tires are 20 times bigger than the sand alone. The bigger the grain size of the shredded tire, the more is the settlement of the mixture.
- As expected, the settlement of the mixtures increases with the increase in the shredded tire content. In addition, the density of the mixtures decreases with the increase in the rubber content.
- The equivalent friction angle of the mixture decreases as the rubber content is increased. The samples with coarser shredded tires have larger friction angles.
- The equivalent friction angle increases as the deformation in the samples augments.
- Although the sand alone shows a dilative behavior, the mixtures only behave contractively. The grain size does not have much influence on the deformational regime.
- According to the elastic theory, the confined elastic modulus was determined. For the mixtures, the samples with the rubber content of 30% have stiffness similar to the content of 100%.as shown in Fig.3. The samples with 20% content have the highest stiffness.
- The size of shredded rubber has an increasing effect on stiffness. This effect is small when it is mixed with sand, while the increase in stiffness with grain size is more obvious in pure samples.