International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:12, No:8, 2018

Evaluation of Shear Strength Parameters of Rudsar Sandy Soil Stabilized with Waste Rubber Chips

R. Ziaie Moayed, M. Hamidzadeh

***Abstract*—**The use of waste rubber chips not only can be of great importance in terms of the environment, but also can be used to increase the shear strength of soils. The purpose of this study was to evaluate the variation of the internal friction angle of liquefiable sandy soil using waste rubber chips. For this purpose, the geotechnical properties of unmodified and modified soil samples by waste lining rubber chips have been evaluated and analyzed by performing the triaxial consolidated drained test. In order to prepare the laboratory specimens, the sandy soil in part of Rudsar shores in Gilan province, north of Iran with high liquefaction potential has been replaced by two percent of waste rubber chips. Samples have been compressed until reaching the two levels of density of 15.5 and 16.7 kN/m^3. Also, in order to find the optimal length of chips in sandy soil, the rectangular rubber chips with the widths of 0.5 and 1 cm and the lengths of 0.5, 1, and 2 cm were used. The results showed that the addition of rubber chips to liquefiable sandy soil greatly increases the shear resistance of these soils. Also, it can be seen that decreasing the width and increasing the length-to-width ratio of rubber chips has a direct impact on the shear strength of the modified soil samples with rubber chips.

***Keywords*—**Improvement, shear strength, internal friction angle, sandy soil, rubber chip.

I. Introduction

WITH the expansion of the transportation industry, many worn-out tires throughout the world enter the environment every year, causing a global environmental problem. Each year, more than 290 million waste rubbers are produced in the United States [1], and Canada produces more than 28 million passenger tires each year [2]. On the other hand, these materials have a very long life span in nature and therefore cannot be easily decomposed; therefore, this high volume of tires should be properly reused or disposed. The worn tires, due to their high tensile strength in the soil, can be considered for reinforcing the soil and to find a solution for reusing the worn-out tires. The use of waste tires is growing in the geotechnical projects. A lot of studies are done on the use of these materials for the reinforcement of soft soils in the road bed, in order to control the erosion of the earth, a lightweight material for the embankment behind the retaining wall and stabilization of slopes. These materials are usually shredded and used as a substitute for grain aggregates. In this regard, for the proper use of rubber chips, a lot of studies have been done to determine the engineering properties of rubber chips and sand-mixed rubber chips [3]-[5]. The results of this research showed that rubber chips and their mix with sand can be used as a lightweight material for the embankment behind the retaining wall and reinforce the soft soils in road construction. Also, according to the results of this study, sand and rubber chips mixtures have higher resistance, compressibility and permeability than unmodified soils. In some cases, environmental assessments have been carried out on the rubber-reinforced embankments by [6]-[8], they concluded that waste tires had less impact on groundwater quality for a 2-year process. Significant advances have been made in using pure rubber chips or full tires as the embankment materials in transportation substructures [2], [6], [9]. Cetin et al. [10] investigated the geotechnical properties of clay and rubber chip mixtures by performing permeability, direct shear and density tests. They found that in certain percentages of fine and coarse rubber chips the shear strength of the mixture increased compared to the pure clay and the adhesion is decreased and the internal friction angle is increased with the increase in rubber chips in the soil. Finally, they suggested that clay- rubber chip mixtures could be used as road aggregates in highways, filling materials behind the bridge piers and embankments behind the retaining wall walls at the top of the phreatic zone. Akbulut et al. [11] investigated the effect of rubber and synthetic fibers on single-axial compressive strength, resistance parameters, and dynamic behavior of clay soils. By carrying out the simple compression tests, direct shear and resonant column tests they reported that in the reinforced samples increasing rubber fiber up to 2%, the single-axis compressive strength increases and then decreased. In case of samples mixed with polyethylene and polypropylene fibers the results indicated in 0.2% of fiber content increases the uniaxial compressive strength. They also found that by adding rubber and artificial fibers to the clay soils the adhesion values, the damping ratio and the shear modulus increase. By increasing the percentage of fiber in the mixture the damping ratio increases and reaches its maximum value in the particular amount of fibers (rubber and synthetic) and then decreases with increasing the amount of fiber. Several studies have been carried out to determine the engineering properties of mixed sand-and-rubber chip substrates [12]-[14]. Lee studied the effect of different confining pressures on samples by conducting triaxial test on rubber chips and sand- rubber chip mixture. The tires used in this study did not have a steel belt. Rubber chips samples showed almost a stress-strain linear result for a range of confining pressures. Sand- rubber chip mixture samples showed a moderate response between rubber chips and pure sand samples [15]. Hataf and Rahimi [16] presented experimental models for research on the use of worn tire rubber chips to increase load bearing capacity. The results

Francisco Cunha is with the Pontifical Catholic University of Rio de Janeiro, Brazil (e-mail: fcunha@inf.puc-rio.br).

indicated that the addition of rubber chips to sand would increase the California bearing ratio depending on the percentage of rubber chips and their dimensional ratios. Ghazavi and Amel [17] carried out a large direct shear test to examine the effect of the dimensions of the waste rubber chips on the shear strength parameters of the sand. Their results showed that for the given width of the rectangular rubber chips, there is only one unique length that gives the greatest friction angle for sand-rubber chip mixtures. They also showed that optimizing the dimensions of the chips for all samples used in their research can increase the initial friction angle up to 25% higher than the non-optimal dimensions. Firat and Cagaty [18] investigated the triaxial behavior of sand-rubber chip mixtures compression using a neural network. In this research the shear behavior of samples reinforced by rubber fibers were investigated. For this study, based on the type of soil SP, the triaxial consolidated drained (CD) test was selected and samples with the weight ratios of 5, 10, 20, 30 and 50 were used where the rubber chips were passed through the filters of 10-40. Standard Proctor Test was done to determine the maximum density and optimum moisture content of samples. Soganci [19] evaluated the impact of rubber on sand- rubber mixtures and the conditions under which the mechanical properties of the mixture were tested. He showed that the addition of rubber chips to sandy soil improves the shear characteristics due to the increase in the internal friction angle. Perez et al. [20] analyzed the effect of the rubber size and content in sand mixtures in critical condition micro-mechanically. In this study, a series of triaxial drained tests were simulated on on a mixture of sand (hard particle) and rubber particles (soft particle) with the discrete element method (DEM). The results showed that regardless of the size of rubber particles, the contact of rubber and sand plays an important role in increasing total soil strength. These results indicate the importance of recognizing the properties of new materials for engineers' skills that the ratio of different rubber sizes and contents has positive or negative effect on strength and ductility the selection of mixes of sand and rubber should be based on the nature of the project.

The purpose of this study is to evaluate the variation of the internal friction angle of sandy soils with modified lignification potential using the waste rubber chips. For this gole, the geotechnical parameters of unmodified soil samples and modified soil samples with waste rubber chips were determined by conducting a drained consolidated three-axial test and analyzed.

II. Experimental Studies

A. Applied Material

The sandy soil in part of Rudsar shores in Gilan province, north of Iran with high liquefaction potential has been used. Fig. 1 shows the sand grading curve. Other details of the sand used are presented in Table I. The sand with two percent volumetric rubber chips (10 and 20 percent) in two levels of density of 15.5 and 16.7 (kN/m^3) and different length to width ratios of the chips is mixed. The rubber used in this research is selected from waste floorings that are removed from the cycle during production and after being used. The width of the chips is 0.5 and 1 cm (Fig. 2). The thickness of the chips is in the range of 0.8 to 3 mm.

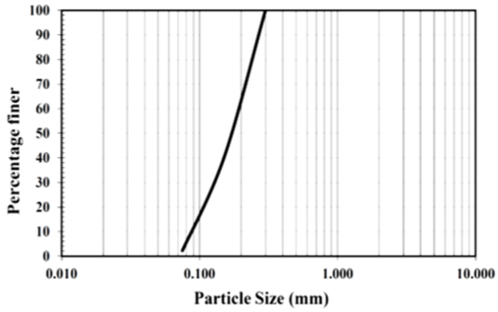


Fig. 1 Grain size distribution curve of tested sand

TABLE I
SAND PROPERTIES

Description	Value
D_{10} (mm)	0.06
D_{30} (mm)	0.13
D_{60} (mm)	0.20
C_U	2.21
C_C	0.94
Minimum dry density (kN/m^3)	15.5
Maximum dry density (kN/m^3)	16.7
Specific gravity	2.67

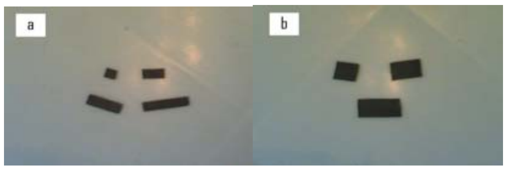


Fig. 2 Two types of rubber with different dimensions a: 0.5 cm width, b:1 cm width

III. Test Program

The triaxial CD tests were done on unmodified and modified soil samples by 2% of waste lining rubber chips (10 and 20 percent) in dry state. The loading speed was 0.5 mm/min, and the 50, 100 and 150 kPa confining pressures were used to conduct triaxial CD test. The unreinforced sand and the almost uniform sand-rubber chip mixture in two percent of the density (85% and 100% of modified AASHTO density) were tested.

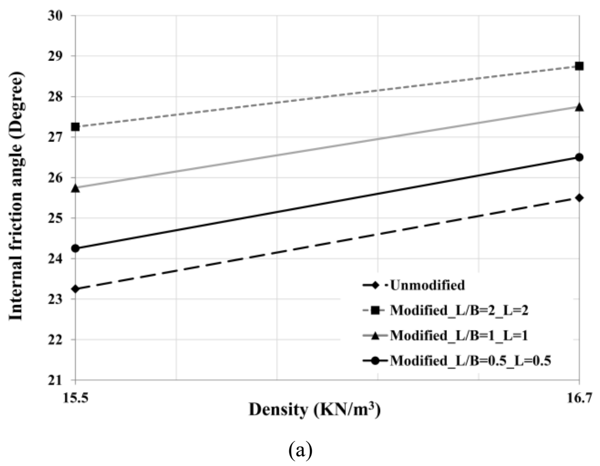
IV. Results and Discussions

Table II presents the results of triaxial CD test on unmodified and modified soil samples with waste lining rubber chips. Based on Table I, it is observed that the modified samples with 20% of the rubber chips have higher internal angles of friction. Fig. 3 shows the variations of internal friction angle of the sand samples with optimum rubber chips (containing 10% rubber chips) and without the rubber chips in the dry state of the samples. With respect to Fig. 3, it can be seen that the addition of rubber chips has a significant effect on increasing the friction angle of sand samples. This could be due to the bridge being built by rubber chips between the sand particles and the increase in interlock of the grains.

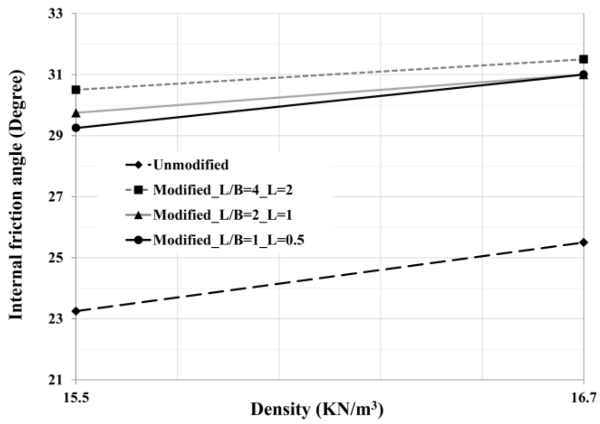
TABLE II
RESULTS OF TRIAXIAL CD TEST ON SOIL SAMPLES WITH OR WITHOUT RUBBER CHIPS

Sample No	Soil density (kN/m^3)	Sample reinforcement condition	Percentage of rubber chips(%)	Chip length (m)	Chip width (mm)	length to width ratio	Internal friction angle (Degree)
1	16.7	Modified	10	2	0.5	4	30.5
2	16.7	Modified	10	1	0.5	2	30.3
3	16.7	Modified	10	0.5	0.5	1	30.0
4	15.5	Modified	10	2	0.5	4	29.0
5	15.5	Modified	10	1	0.5	2	28.5
6	15.5	Modified	10	0.5	0.5	1	27.8
7	16.7	Modified	10	2	1	2	27.5
8	16.7	Modified	10	1	1	1	26.8
9	16.7	Modified	10	0.5	1	0.5	25.5
10	15.5	Modified	10	2	1	2	26.0
11	15.5	Modified	10	1	1	1	24.5
12	15.5	Modified	10	0.5	1	0.5	23.5
13	16.7	Modified	20	2	0.5	4	31.5
14	16.7	Modified	20	1	0.5	2	31.0
15	16.7	Modified	20	0.5	0.5	1	31.0
16	15.5	Modified	20	2	0.5	4	30.5
17	15.5	Modified	20	1	0.5	2	29.8
18	15.5	Modified	20	0.5	0.5	1	29.3
19	16.7	Modified	20	2	1	2	28.8
20	16.7	Modified	20	1	1	1	27.8
21	16.7	Modified	20	0.5	1	0.5	26.5
22	15.5	Modified	20	2	1	2	27.3
23	15.5	Modified	20	1	1	1	25.8
24	15.5	Modified	20	0.5	1	0.5	24.3
25	16.7	Unmodified	0	-	-	-	25.5
26	15.5	Unmodified	0	-	-	-	23.3

In Fig. 4, a variation in the internal friction angle for the change in length to width ratio of samples is presented. Considering the results, it is observed that decreasing the width and increase of the length to width ratio of the rubber chip increases the shear strength of the modified soil samples. As in samples with higher L/B, the effect of condensation is reduced.



(a)



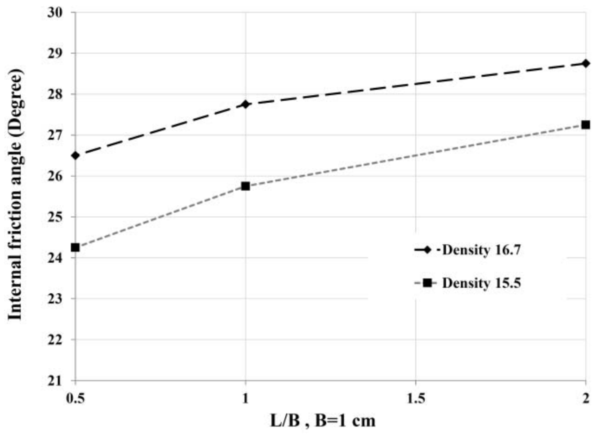
(b)

Fig. 3 Changes in the internal friction angle for change in chip dimensions and density of soil samples in dry state. (a): chip width of 1 cm; (b): chip width of 0.5 cm

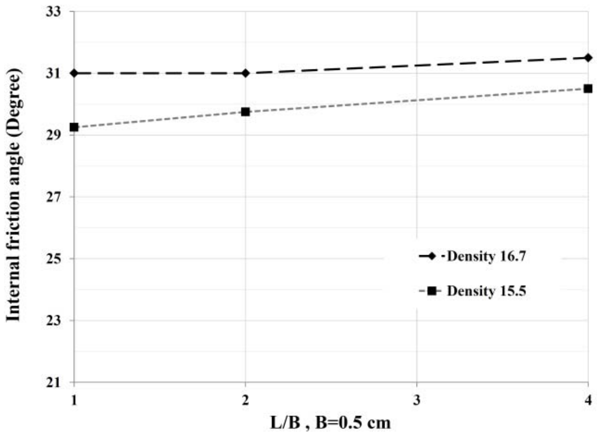
V. CONCLUSION

The purpose of this study is to evaluate the variation of the internal friction angle of sandy soils modified with waste rubber chips. For this purpose, 26 triaxial CD tests were performed unmodified and modified samples with waste lining rubber chips. The shear strength parameters of these specimens were evaluated and analyzed. The most important results of the research are as follows:

1) According to the results, it is seen that the addition of rubber chips has a significant effect on increasing the internal friction angle of sandy soil samples. This could be due to the bridge being built by rubber chips between the sand particles and the increase in interlock of the grains.
2) The width and the length-to-width ratio of rubber chips have a direct impact on the shear strength of the modified soil samples with rubber chips. As the L/B of rubber chips increases, the effect of condensation is reduced.



(a)



(b)

Fig. 4 Changes in the internal friction angle for change in length-to-width ratio and density of soil samples in dry state. (a): chip width of 1 cm; (b): chip width of 0.5 cm

ACKNOWLEDGEMENT

The authors would like to confirm the data support of this research by Satavand Banaye Payevar Consulting Engineers.

REFERENCES

[1] Rubber Manufacturers Association _RMA_. 2004. "US scarp tire markets, 2003 edition." 7th Biannual Rep. of the Rubber Manufacturers Association, 1–51.
[2] Garga, V. K., and O'Shaughnessy, V., 2000, "Tire-reinforced earthfill. Part 1: Construction of a test fill, performance, and retaining wall design." Can. Geotech. J., 37, 75–96.
[3] Yang S, Lohnes RA, Kjartanson BH. Mechanical properties of shredded tires. Geotech Test J 2002; 25(1):44–52.
[4] Youwai S, Bergado DT. Strength and deformation charactereristics of shredded rubber tire–sand mixtures. Can Geotech J 2003; 40:254–64.
[5] Zorbberg J. G., Cabral A. R., Behaviour of tire shred–sand mixtures, Canadian Geotechnical Journal, 2004, 41, pp. 227–241.
[6] O'Shaughnessy, V., and Garga, V. K., (2000b), "Tire-reinforced earthfill. Part 3: Environmental assessment." Can. Geotech. J., 37, 117–131.
[7] Humphrey, D. N., Katz, L. E., 2002. Water quality effects if using tire shreds below the ground water table, Final Report, Department of Civil and Environmental Engineering, University of Main, Orono, ME.
[8] Moon, C. M., 2003, Environmental effect of waste tires as earth reinforcing material. Master Thesis, Inha University (in Korean).
[9] O'Shaughnessy, V., and Garga, V.K. 2000a. Tire-reinforced earthfill.Part 2: Pull-out behaviour and reinforced slope design. Canadian Geotechnical Journal, 37: 97–116.
[10] Cetin, H., Fener, M. and Gunaydin, O., "Geotechnical properties of tire-cohesive clayey soil mixtures as a fill material", Engineering Geology, 88 (1–2), pp. 110-120, (2006).
[11] Akbulut, S., Arasan, S. and Kalkan, E., "Modification of clayey soils using scrap tire rubber and synthetic fibers", Applied Clay Science, 38(1-2), pp. 23-32, (2007).
[12] Warith, M. A., and Sudhakar, M. R., "Predicting the compressibility behaviour of tire shred samples for landfill applications", Waste Management, 26, pp. 268-276, (2006).
[13] Yilmaz, A. and Degirmenci, N., "Possibility of using waste tire rubber and fly ash with Portland cement as construction materials", Waste Management, 29(5), pp. 1541-1546, (2009).
[14] Ganjian, E., Khorami, M. and Maghsoudi, A. A., "Scrap-tyre-rubber replacement for aggregate and filler in concrete", Construction and Building Materials, 23(5), pp. 1828–1836, (2009).
[15] Lee, J.H., Salgado, R., Bernal, A., and Lovell, C.W. 1999.Shredded tires and rubber sand as lightweight backfill. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 125(2): 132–141.
[16] Hataf, N., & Rahimi, M. M. (2006). Experimental investigation of bearing capacity of sand reinforced with randomly distributed tire shreds. Construction and building materials, 20(10), 910-916.
[17] Ghazavi M., and Amel Sakhi M., (2005), "Influence of Optimized Tire Shreds on Shear Strength Parameters of Sand", International Journal of Geomechanics, ASCE, Vol. 5, No. 1, pp 58–65.
[18] Firat, A., Cagaty, A. (2012), "Triaxial compression behavior of sand and tire wastes using neural networks." J. of Geotech.andGeoenviron. Engrg., ASCE, pp. 441-452., london.
[19] Soganci, A. S., (2015), Strength characteristics of tire sand mixtures, Soil Mechanics and Foundation Engineering, Vol. 51, No. 6.
[20] Lopera Perez. J. C., Kwok. C. Y., Senetakis, K., (2017), Micromechanical analyses of the effect of rubber size and content on sand-rubber mixtures at the critical state, Geotextiles and Geomembranes, Volume 45, Issue 2, April 2017, Pages 81-97.