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STABILIZATION OF SANDY SOIL USING RECYCLE WASTE TIRE CHIPS

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ABSTRACT: Waste or scrap materials cause a lot of environmental problems and lead to economic problems. To minimize these problems, it is necessary to find safe ways to reduce the harms on environmental issues and on the economy accompanying with accumulated large wastes. This study introduces an attempt to improve sandy soil using a new additive in form of waste tires chips instead of conventional kinds used in the soil stabilization. Different percentages of waste tire chips are hand mixed with dry sand as a trial to stabilize the sand with local cheap materials. Some geotechnical properties of composite specimens of (soil + tire chips) were studied and the main findings of testing approved the ability to stabilize sand effectively using scrap tire chips. Shear strength of sand was increased as a result to increase both friction angle and cohesion after adding tire chips to sand. A significant reduction in specific gravity and maximum dry density with a little reduction in optimum moisture content was marked with increase tire chips content in sand due to the low unit weight of tire chips. Analyzing the results gained from CBR test showed that sand stabilized with tire chips gave CBR more than about 1.6 times compared with pure sand which means the load bearing capacity of treated sand is increased due to increase the physical bonds between sand particles and tire chips.

Keywords: Shear Strength, Waste Materials, Tires Chips, CBR, Sand Improvement

1. INTRODUCTION

The materials adding to a soil as improvement additives are wide-ranging and have a variety of properties, forms, and attributes. Generally, it ranges from natural soils to chemical additives and even reused waste products. One of these waste materials is tire chips that elected as a waste material to stabilize sandy soil after recycling.

Soil improvement may gain by adding some materials or mixed with soil in situ to improve the soil behavior or to eliminate undesirable properties by creating new bonds between particles differ partially or totally from that in the original soil.

The engineering properties of soils can be enhanced through the addition (or subtraction) materials to (or from) the soil. Improvement of soils by using admixtures (material added to the soil) is often called soil stabilization. The recent studies stated that the solid waste additives such as waste bags, rice husk ash, fly ash and waste tires are commonly used for this purpose [1], [8].

The solid waste term includes all the solids and semi-solids. Improper management of solid wastes causes adverse effects ecology which may lead to cause a possible outbreak of diseases and epidemics. Solid wastes are broadly classified into three groups' namely industrial waste, agricultural waste, and municipal waste apart from other categories of wastes [10].

The waste tires have been become alarming volume in many industrialized countries, causing an acute need to concern the engineering alternatives for the purposive reuse of to discard scrap tiers **.**

The reuse of tires as tire chips, tire shredded or crumb tire contributes in growing the environmental and economic issues, adding to solving some of the undesirable characteristics of soils such as low strength.

2. AIM OF STUDY

Waste materials cause a lot of environmental problems and economic problems. To mitigate these problems, it is necessary to find safe ways to reduce its harms on the environment and on the economy. The difficulty of tires composition prevents the recycling process and reuse on vehicles; therefore, recycling and use of these materials as additives in new applications are considered the best solution to get rid of waste materials.

The aim of this study tries to introduce alternative kinds of materials used in soil stabilization instead of traditional materials such as cement or lime etc… which have a high cost. Therefore, this study introduces a useful method to decrease the environmental contamination of waste tires due to locally available in Iraq through by these additives kinds to improve sandy soil.

3. BACKGROUND OF STUDY

The soil in any site may not be satisfied “partially or wholly” the construction engineering requirements.

Recently, increasing the soil efficiency using cheap materials has been adopted in many countries to eliminate the undesirable properties and increase areas for construction.

Two methods are implemented in soil stabilization: (mechanical stabilization and chemical stabilization). Mechanical stabilization achieves through using compaction or vibration methods to alter the physical properties of soil while the chemical stabilization achieves the desired effect depending on chemical reactions between stabilizer additives and soil minerals to create new bonds.

When the site investigation results indicate that the soil condition is not as strong as expected in terms of bearing strength, settlement or liquefaction resistance, engineers have to find the best solution to improve the ground condition. The conventional ground methods adopted in practice include vibro-compaction, stone columns, preloading, de-watering and deep mixing and etc.. However, their effectiveness is reasonably good for a large scale project, but the implementation cost of each method is enormously high. Thus, a cost-effective ground improvement method is profoundly important for engineers to consider, preferably one which is applicable to both new design and existing structures [4].

In geotechnical works applications, waste tires are used after recycled to create new forms (shredded, crumb and chips) to suit the soil particles. Whole scrap tires may widely use in various applications of civil works as well as highway crash barriers or in marine docks [13], reinforcement the pavement subgrade [18], [19].

When waste tires are reused as a construction material rather than disposed or burned, there are unique properties can once again be beneficial in a sustainable material stream. Waste tires could be effectively used as a substitute for virgin construction materials made from nonrenewable resources [14].

A few of ASTM standards have already been established on the proper reuse of recycled scrap tires. The one best suited for geotechnical applications is ASTM D6270-98, titled “Standard Practice for Use of Scrap Tires in Civil Engineering Applications” (ASTM, 1998).

Although the use of scrap tires in field projects has been widespread with some 40 state highway agencies conducting some sort of research, its use is still deemed experimental. Ample researchers have been investigated to identify the ability to use recycled tires in soil stabilization, a bit of these are listed below.

Chips tires can be used as a fill material in embankment construction due to its low unit weight and high strength. Adding chips rubber tires to soil not only reduce the deformation characteristics but also improve the strength of the backfill and cause a reduction in self-heating problem [3], [13].

In highway embankment design, some properties of waste or scrap tires, as well as resiliency, strength, durability and high frictional resistance, are considered very important factors to improve its performance [5], [14].

Addition of shredded tires to sand improves the shear strength effectively as a result to increase the friction angle between sand particles [2].

Recycled materials were used to stabilize marginal materials. It was found that the use of such materials in roadway and highway construction gave a clear advantage in terms of improvement of the engineering properties of the foundation, subbase, base, slopes, or embankment materials [1].

An experimental study conducted on a specimen of fine sand mixed with 10% to 50% tire chips showed that 30% of waste chips content was improved the strength of sand effectively [7].

Direct shear test for sand – scrap tires chips mixtures approved the ability of tire chips to improve the shear strength characteristics of sand, [6], [15].

In the current decade, many kinds of researchers have been investigated the ability to use large size tire chips to improve sandy soil. The results showed the sand samples contain tire chips exhibited more shear strength and liquefaction resistance [4], [11].

It worthy noted, in spite of the past studies gave the evidences on the beneficial effect of tires inclusion when mixed with soil, the quantification of such improvement, assessment of the effect of the soil density and optimum of tires content deserve further study. In addition, despite attempts to sieve the tire chips prior to testing, the effects of tires size and aspect ratio have not been quantified.

4. METHODOLOGY AND EXPERIMENTAL WORKS

Various experimental tests are performed on a sand and sand-tire chips mixing to characterize the sand used and obtain the influence of adding tire chips on engineering properties of stabilized sand. Disturbed sand was taken at depth of (1-1.5) m and according to the unified soil classification system USCS, the soil type is classified as poorly graded sand and consists of 97% sand and 3% finer particles that yielded by sieve analysis as shown in Fig.1. To create a good interlocking between waste tires and sand particles, waste tires are grinded using the mechanical machine and passed through standard sieves to get uniform particles filler in form of tire chips which consider more finely and uniformly sized compared with tire shreds as stated by Singh and Vinot, (2011) [7]. To satisfy the definition of tire chips used according to ASTM D 6270, the particles of tire chips are ranged from (0.6 - 4.75) mm as shown in Fig. 1. Standard specifications of testing were followed to concern the sand properties. The details of physical

properties are tabulated in Table 1.

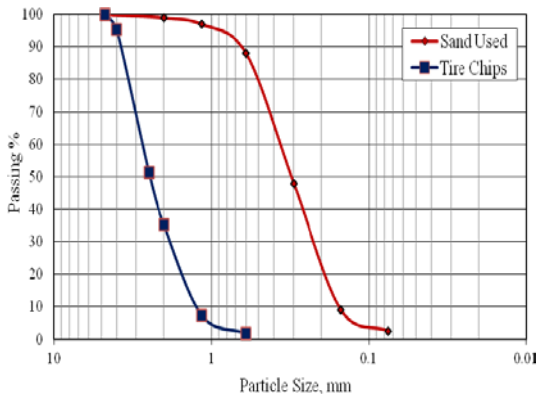

Fig.1 Grain size distribution of the sand and Tire Chips used

Table 1 Identifiable characteristics of sand used

Soil Property	value
Specific gravity, GS	2.64
Coefficient of uniformity, Cu	2.55
Coefficient of curvature, Cc	0.79
Passing #200	97
USCS	SP
Optimum moisture content, O.M.C (%)	9.8
Max. dry unit weight,γdry Max. (kN/m^3)	19.6
Sulphate content, SO3 %	0.72
Gypsum Content %	1.55

5. RESULTS AND ANALYSES

A testing program was implemented to investigate the influence of tire chips on sand characteristics when mixed manually with different percentages (2, 4, 6 and 8%) by weight. Prior to the mixing, the proportional weights of sand and waste chips are predetermined to prepare many sand-tire chips samples that using in specific gravity, compaction test, CBR test and direct shear tests.

5.1 Specific Gravity

Prior to determining the specific gravity of sand-tires chips mixtures, a specific gravity of tire chips was determined and it was found to be equals 1.21. A density bottle of 100 ml was used to concern the effect of waste chips on specific gravity on sand accordance with ASTM D854 as shown in Table 2. It can be seen that a reduction in the values of specific gravity are occurred with the increasing of waste content in the sand because the tire chips are considered as a granular material with low specific gravity.

The reduction benefit of specific gravity appears to attain the maximum dry unit weight of soil for a given water content when will be no air in the void spaces with 100% degree of saturation [17].

Table 2 Effect of tire-chips on specific gravity

Tire chips %	0	2	4	6	8
Gs	2.64	2.60	2.57	2.54	2.45

5.2 Compaction Characteristics

Modified compaction test is carried out on sand-tire chips mixtures to obtain the maximum dry unit weight (MDD) and optimum moisture content (OMC) as per IS-2720-Part-8. Heavy tamping was used instead of vibration method to avoid the segregation during shaking the mixtures. CBR mold with dimensions of 152.4 mm in diameter and 178 mm in height was used to obtain compaction characteristics. Fig. 2 shows the variation of dry unit weight with a moisture content of sand-tires chips mixtures.

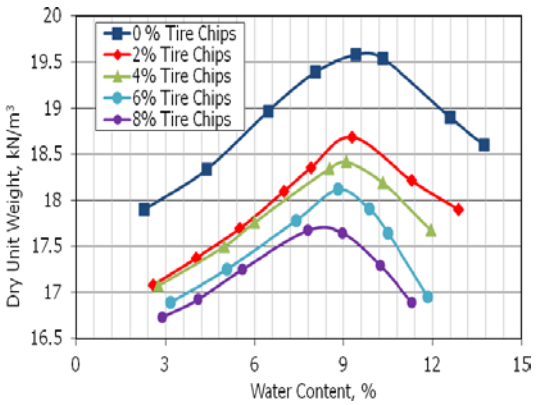

Fig. 2 Compaction curves of sand –tires chips mixtures

It can be evidenced that when the waste tires content increased in the sand mixture, dry density is reduced due to nature of tires chips which considered as a lightweight fill material. This reduction has a benefit in embankment construction when such mixture is used in fills, the lateral earth pressure will decrease.

Also, it can be observed that about of 10% reduction in optimum moisture content is achieved when tires chips increased in sand mixtures up to 8% therefore; the tire chips have a little influence on OMC.

5.3 Shear Strength Characteristics

Direct shear tests are carried out on sand-tire chips mixtures by adding tire chips varying from 0% to 8%

by weight using (6×6) cm shear box accordance with ASTM D 3080. Tire chips are hand mixed with sand and tamped into the shear box in a multilayer to achieve the optimum density. Prior to concern the shear strength parameters of sand used, the friction angle and cohesion of tire chips were determined and they found to be equal to 19° and 9 kPa respectively.

All direct samples are prepared at optimum moisture content at a constant rate of 0.5 mm/min. Shear box test reveals that sand used has 4kPa cohesion and friction angle of 35.5°. Findings of shear tests indicate that adding of tire chips to mixture increases the friction angle and cohesion as shown in Fig. 3. The increase of friction resistance between particles attributed to the frictional behavior displayed by tire chips. Physical bond between sand particles and tire chips causes the cohesion to increase gradually. Typically, the density of pure tire chips fills ranges from the frictional response of sand in mixtures; therefore, the shear strength will be increased due to creating an additional frictional component.

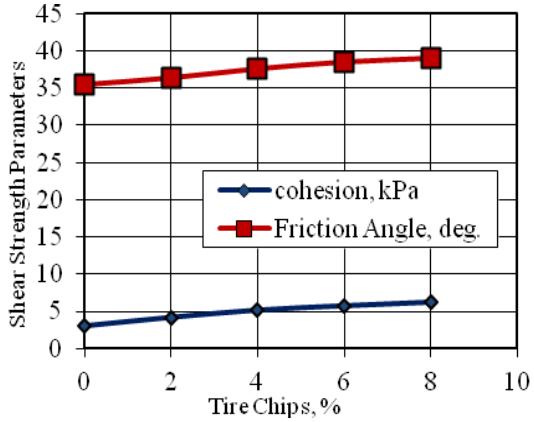

Fig.3 Results of direct shear test of sand-tire chips mixtures

5.4 California Bearing Ratio (CBR) Results

Accordance with ASTM D1883-05, CBR test is carried out using a standard plunger of 50 mm diameter and with rate of 1.25 mm/min to evaluate the mechanical strength of sand-tire chips mixtures (load-bearing capacity). The testing specimens are compacted in CBR mold at the optimum moisture content and 100% compaction degree. A surcharge pressure of 2.5 kPa was applied on CBR mold after placing in the position to penetration plunger. Thereafter, the displacement of the piston was determined to correspond to the applied pressure using pairs of dial gauges with an accuracy of 0.002 mm.

Fig. 4 depicts the results of soaking CBR test of sand-tire chips mixtures. It can observe that the difference in stress between every two consecutive curves in reinforced sand samples increases with penetration.

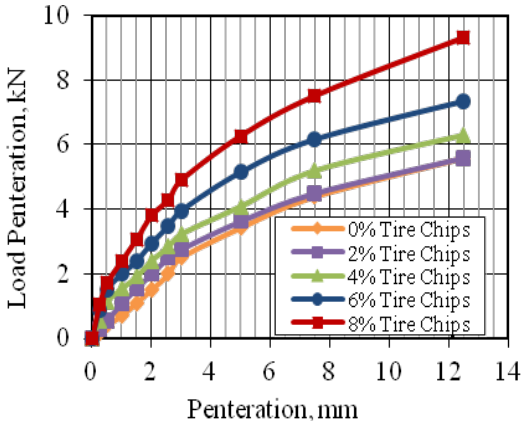

Fig. 4 Load - penetration curves treated sand with different percentages of tire chips

Fig. 5 shows that the increasing of tire chips content in sand tends to increase the piston stress for a constant penetration in the CBR specimens. These increments return to the increasing of the bonds between particles of sand and tire chips that leading to ability of sand – tires mixture to sustain higher loads compared with unstabilized sand. Also, the addition of amount of tire chips into the sand leads to dispersing and distributing the applied stress to sand, therefore, the bearing capacity of stabilized sand with waste tire chips will be increased.

Increasing tire chips content in the sand leads to increase the percent improvement in CBR values of stabilized sand from 2.3% to 21.5% when the tire chips content increase from 2% to 8% respectively as shown in Fig. 6.

Percent increase was determined according to the following equation:

$$CBR_{PI} = \frac{CBR_{TS} - CBR_{UTS}}{CBR_{URS}} \times 100 \quad (1)$$

Where:

CBR_{PI} = Percent increase in CBR.
CBR_{TS} = CBR value for treated sand.
CBR_{UTS} = CBR value for untreated sand.

Also, Secant modulus (K_s) which defined as the ratio of load, σ in kPa at a penetration of 2.5 mm to the penetration of 0.0025m was determined for a stabilized sand from the CBR results using the following equation:

$$K_s = \frac{\sigma\ @2.5mm}{0.0025} \quad (2)$$

Where:

K_s = Secant Modulus (MN/m^2).
σ = applied load.

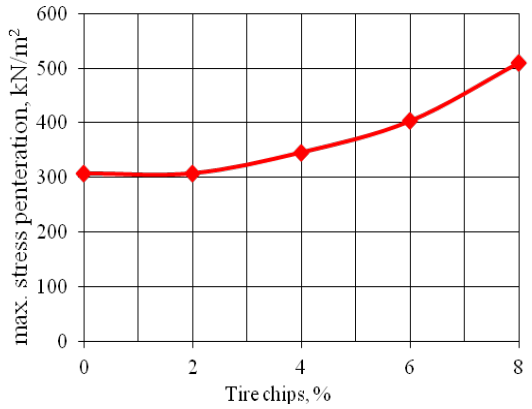

Fig. 5 Stress - penetration plot of sand-tire chips mixtures in CBR tests

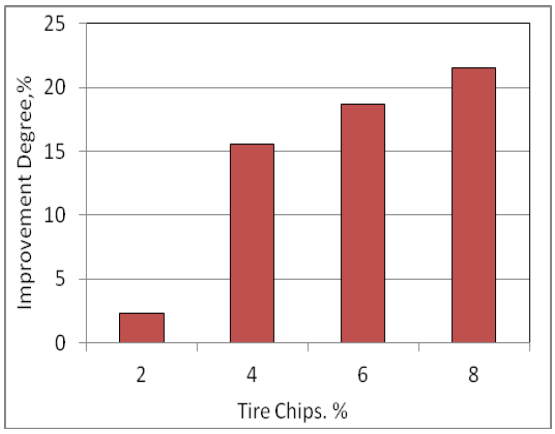

Fig. 6 Effect of tire chips on CBR improvement of sand mixtures

The analysis of secant modulus calculated using Eq. (2) above shows to a noticeably increasing due to the inclusion of tire chips in the sand as shown in Fig.7.

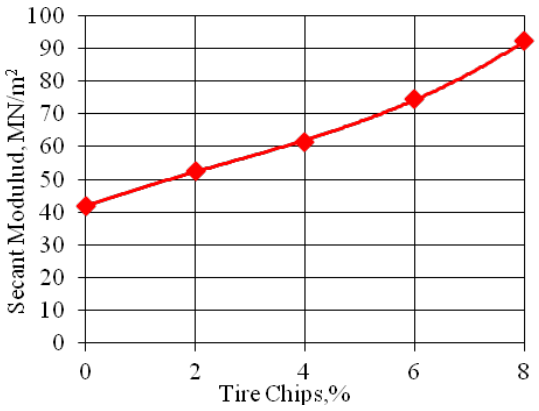

Fig.7 Variation of secant modulus with tire chips content in reinforced sand

6. CONCLUSIONS

Based on testing results of sand-tire chips mixture, the following conclusions can be drawn:

Tire chips can effectively use to improve the mechanical properties of sandy soil. Addition of tire chips to sand decreases the specific gravity and dry density and decreases the optimum moisture content slightly. This occurrence has a benefit to decreasing the lateral earth pressure on retaining walls if the tire chips are used as a fill material. Scrap tire chips increase the shear strength of sand due to increasing the physical bonds between soil particles as a result to increase the friction angle and cohesion. The soaking CBR was increased up to more 1.6 times compared with unstabilized sand when the tire chips content inclusion increase up to 8% due to increasing of confining pressure and sustain higher loads. Using scrap materials will contribute to reducing the cost of construction, and solving disposal problems of these materials and towards the green environmentally without disposal materials

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