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RESEARCH ARTICLE
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Effect Rubber Tire Granulated on Properties of Expansive Soil

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Abstract. In recent decades, the accumulation of discarded tires has resulted in environmental issues all around the world. Using recycled tire material to enhance the characteristics of problematic soils is the piratical solution to this problem. This article reports an experimental investigation of the effect rubber granulated on .expansive soil sample from shahat city was mixed with different percentages (0%, 2%, 4%.6%,8%,10%, and 15%)by weight of granulated rubber. The compaction and unconfined compressive strength tests are carried out on natural samples and samples added with (2%,4%,6%,8%,10%and 15% rubber granulated. according to the results of the test, the maximum dry density decreased when increasing the rubber content and increasing the optimum water content until reachto8%. The maximum unconfined compressive strength through 3 days at approximately 2%. The Granulated Rubber and soil mixture played a role in postponing the crack development.

Keywords: expansive soil, compaction, unconfined compressive strength, effect, rubber granules.

Introduction

Expansive soils are ones whose volume significantly changes as a result of changes in their water content, engineering structures are severely harmed by expansive soils because they have a tendency to modify their volume to a significant degree[1] numerous studies from past to the present have examined the use of various techniques and materials to enhance expansive soils, the use of addition like lime, blast furnace, fly ash, cement Or scrap tires to improve expansive soils is extensively documented[2-6]. however, the increased cost of cement and lime in recent years has driven up the project's overall cost, and from another side, the elimination of industrial waste such as fly ash, granulated blast furnace ash, and scrap tires is a problem the world is currently confronting consequently, it was employed in engineering projects to lower the cost of disposing of these wastes. one of the most important wastes that affect the environment and the most abundant is scrap tires. the scrap tires and products (such as tire crumb, tire shreds, and tire granulate rubber) numerous researchers have examined the use of rubber in enhancing soil properties, where it has been found to be effective.
More than 30 years have been spent researching the possibility of utilizing rubber tire used likes in various civil engineering projects [7-9]. with types of soil and with other improvement additives, M.saberian et al.2016 studied an experimental investigation of the effects of adding shredded tire chips with cement on

peat soil[10], and G.venkatappaRao and Rakesh studied compressibility and strength of sand-tire chips mixture[11].

There are many studies that dealt to determine its physical and mechanical properties with soil by the use of rubber as reinforcement material and tested by several laboratory tests such as compaction, California bearing ratio(CBR), direct shear, and triaxial test[12, 13].

The main objectives of this research study are:

• To conduct an experimental investigation for the understanding and evaluation of the interaction between clay soils and granulated rubber.

• To study the improvement of clay soil using non-costly additive granulated rubber.

• To reduce the influences of granulated rubber on the environment.

• To experimentally examine the effect to add rubber on some of the mechanical properties of clay soil.

Scope

The following sections will be carried out to achieve the research's objectives.

- Compaction test: To determine the compaction characteristics of clay soil with and without reinforcement.
- Unconfined compression test: To determine the unconfined compression strength of research a samples.

Significant research

The most important, widespread, and publicized geologic hazards are expansive soils. Such soils are regarded- as poor–quality construction materials. And the side-by-side use of scrap tires has been a hot topic to address environmental issues and advance economic growth because they are dangerous industrial and solid waste that would substantially harm human health and pollute the ecological environment. The re-utilization of waste materials is a crude move toward an economical future; reusing discarded and recyclable materials is becoming more and more common in civil engineering worldwide. The research reported here aimed to experimentally study the addition of different percentages of rubber granulate to expansive soil to determine the maximum dry density (MDD) and optimum water content (OWC) of soil and soil-rubber mixtures. And also to determine the highest strength through 3 days using an unconfined compressive strength test.

Materials and methods

Sample collection

The soil used for the study is clay soil from eastern, Libya, city of Shahat. Soil samples a location is shown in (Fig.1). The soil was extracted from a depth 0.5meter below the soil surface

Geotechnical Properties of Soil Materials

There were two materials used for this study: the soil was gathered and air dried for our test from a depth of 0.5 meters in shahhat city, the index characteristics of soil samples were calculated in accordance with American standard ASTM. The natural water content determines based on ASTM D2216-19. Laboratory tests conducted to obtain physical properties like specific gravity accordance with ASTM D854, Atterberg's limits based on ASTM D4318, compaction tests based on ASTM D 698 and unconfined compression test based on ASTM2166-06. The results are shown in Table 1.

Fig.1. Soil sample collection site in shahat Libya

Table 1. Clayey Soil physical characerization.

parameters	Value	Method
Field density(g/cm³)	1.58	ASTM D-1556
Natural moist content (w)%	34.75	ASTM D-2216
Liquid limit(LL)%	49.04	ASTMD-4318
Plastic limit(P.L)%	21.89	ASTMD-4318
Specific gravity(G.s)	2.87	ASTM D-854
USCS	CL	Unified Soil classification system
Plastic index(PI)%	27.15	= (LL-PL)
Liquid index(LI)%	0.47	=(W-PL/PI)
Consistency index(CI)%	0.53	=(LL-W/PI)
Swelling index	70%	Free swell test

Granulated Rubber (GR)

The granulated rubber used herein was supplied from a local tire manufacturing plant in Benghazi. Fig. 3 shows the gradation curve for the used material. The size of the granulated rubber ranges from 0.6, 1.18 and 2 mm as shown in Fig. 2. Furthermore, its uniformity (Cu) and curvature (Cc) coefficients are 1.55 and 0.95, respectively. According to ASTM D6270 [1] classification of tire shreds, the material used falls in the category of granulated rubber, which has a particle size range of 0.425 to 12 mm. The Physical properties results of Granulated rubber (Gr) are shown in Table.2.

Fig. 2. The size of Granulated rubber.

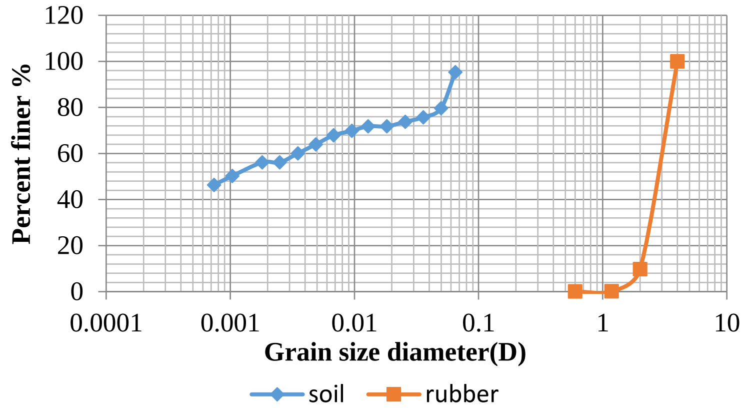


Fig. 3. The sieve analysis of soil and Granulated rubber.

Table 2. The properties of rubber

Properties **Physical properties**	**Value/ Description**
Water adsorption	4%
Specific gravity	0.99
Permeability(cm/sec)	1.46
Grain size distribution and classification	
D10(mm)	2.0055
D30(mm)	2.44
D60(mm)	3.11
USCS	Poorly grade sand(SP)

Specimen preparation

Six different percentages of rubber were added to the soil by mass of the soil (0, 2%, 4%, 6%, 8%, 10%, and 15%) with the intention of acting as soil reinforcements.

free swell tests were carried out on soil according to[14] as well as the compaction test done to investigate the impact of adding rubber to clay soil. In this test, the free swell test was used to investigate the soil's swelling. A graduated free-swell jar with a capacity of 100 ml was filled with water after a 10 g sample of air-dried soil that had passed through a number 40 sieve had been added. The sample was left in a container until the maximum swelling level was reached, at which point the recorded value was calculated using the initial 10 ml value and expressed as a percentage. Fig. 4, displays a free swell jar set for settling. As for the compaction test; the summarization of the idea of the test; put the soil in mold, the mold's volume (921.733cm^3) and the diameter (3.93in) compact the air-dry soil (5kg) on three layers of about 25 times for each layer by using the hammer (5.5Ib) falling from height (12 in). The compaction test was carried out on the sample of clay and the mixture soil- rubber. Fig. 5, clarifies the compaction test. In Unconfined compressive strength, tests were carried out in accordance with ASTM D-2214 on the specimens of 50 mm dia. and 100 mm length prepared at the maximum dry density (MDD) and optimum moisture content (OWC) of standard Proctor by compaction method. Fig. 6, clarifies the preparation of the samples of UCS of soil and mixtures.

Fig. 4. The free swell of soil (a) and (b).

Fig. 5. The Compaction test.

Fig. 6. The samples of UCS

Results and Discussions

compaction test

one of the tests that evaluate the performance of rubber in soil improvement is compaction in terms of determining the maximum dry density and the optimum water content, the addition of rubber percentages (2%,4%,6%,8%,10%and15) gave an improvement in the optimum water content(OWC), as the OWC of the soil-rubber mixture exceeds the OWC of the pure soil(20.04).where when the ratio was 2%,4% and6% they gave (23.60,25.66 and 27.84 respectively. as the percentages of rubber increase, the value of the OWC increases until it reaches its maximum value at 8%(28.82) and then they start to decrease at 10(23.51) and 15(22.76), the decrease in OWC due to decrease absorption capacity for crumb rubber. . In the beginning, the reason for the increase in moisture content is due to the excess water absorbed due to the porous nature of the tire and the subsequent increase in OWC is also likely the cause of additional water being absorbed within the flocculent soil structure, and The increased water content was attributed to the combinations of clay and tire crumbles needing more water to compact [15]. As for the maximum dry density (MDD), the higher the percentage of rubber, the lower the dry density, with 15%being the lowest value for the dry density. Because certain somewhat heavy soils were partially replaced with light-weight tires, the MDD of all treated soil decreased (specific gravity of rubber 0.99) [16]. Fig. 7 and Fig. 8, show the results of the compaction test.

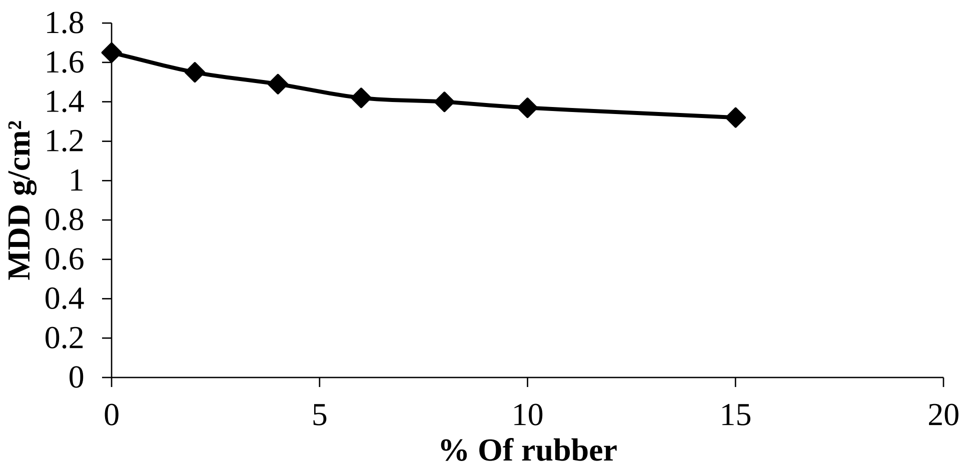


Fig. 7. Max dry density per percentage of Granulated rubber.

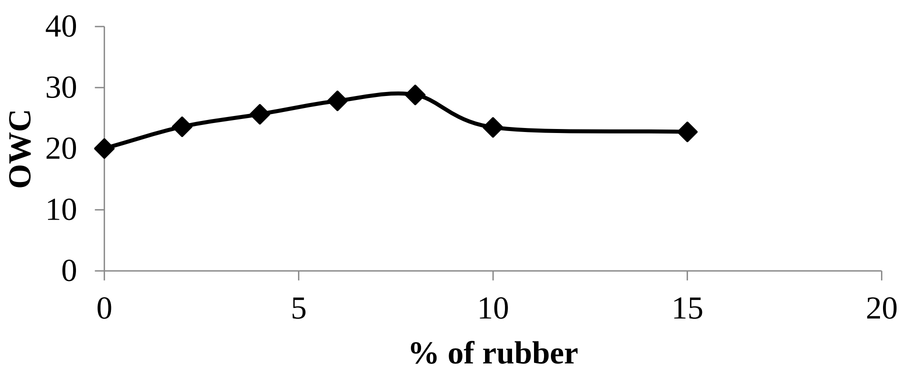


Fig. 8. The OWC per percentage of Granulated rubber.

Unconfined compression test

Effect of Granulated Rubber content on UCS in 3 days (dry case)

Stress-strain curves obtained from the UCS tests in the dry case for 3 days, for natural soil and different soil-rubber composites are provided in Fig. 9. The pure soil exhibited a peak UCS strength of q_u= 568.29 kN/m². Whereas reinforced with2%, 8% and10% rubber q_u measured as 783.95kN/m², 664.8465kN/m² and727.2005kN/m² (the highest strength) respectively. With the inclusion of 6%, 4%, and 15% these values dropped to 559.78kN/m²,222.11 kN/m²and 599.69 kN/m² respectively, which is less than natural soil. The failure axial strain is a measure of a material's ductility, with higher values indicating a more ductile [17] According to the optimum moisture content, the needed amount of water was added to the clay soil-rubber mixture, the Samples with lower moisture content give higher strength than those with higher moisture content, as 2% with water content (23.60) within 3 days gave higher strength (similar to results [18]) than all samples with high moisture content. Although 8% has a high moisture content(28.82), it gave a higher strength than the natural soil strength, because within 3 days it got more dry than the rest of the samples, and it turned into a more harder material.

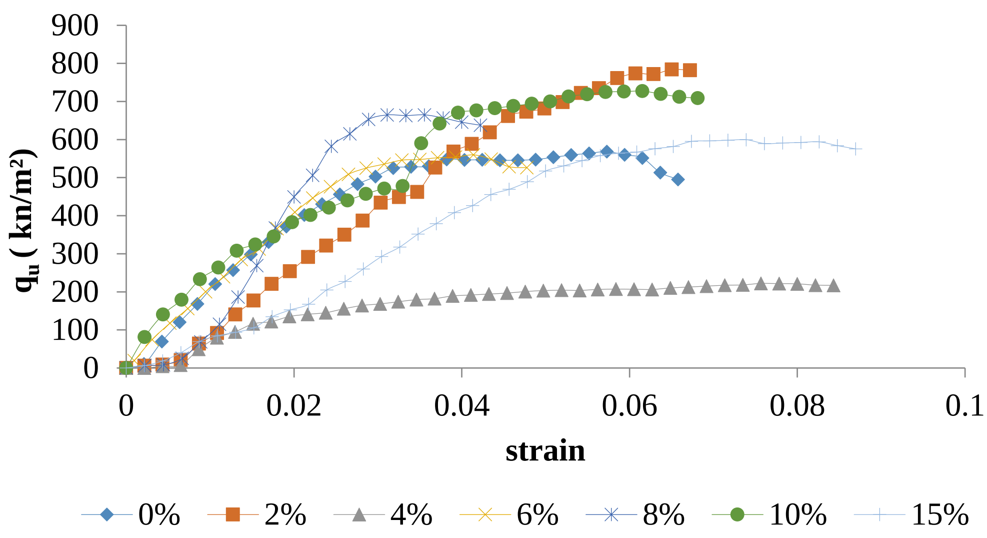


Fig. 9.UCS of soil and soil-mixtures in 3 days (dry case)

Effect of Granulated Rubber content on UCS in 3days (wet case)

According to the Fig. 10, in saturated specimens chosen are improved by increasing the 2% of GR with a value of 77.05231kN/m², followed by soil without reinforcement 72.870kN/m² as for the rest of the ratios (4%,6%,8%, 10%, 15%) with percentages 63.11 kN/m², 69.167 kN/m², 27.409 kN/m², 31.02559 kN/m², and 50.672 kN/m² respectively. they give a strength of less than 0% (72.870kN/m²). The explanation for the increase in strength in some additives and the decrease in others is attributed to the water content. The higher the moisture content, the higher the strength, and the higher the moisture content, the lower the strength. The compressive strength of clay soil was found is decreased with an increase in rubber content [19]. As for the strain failure, the value of the strain increases as the percentage of rubber increases [20], and with increased water content the strain also increases.

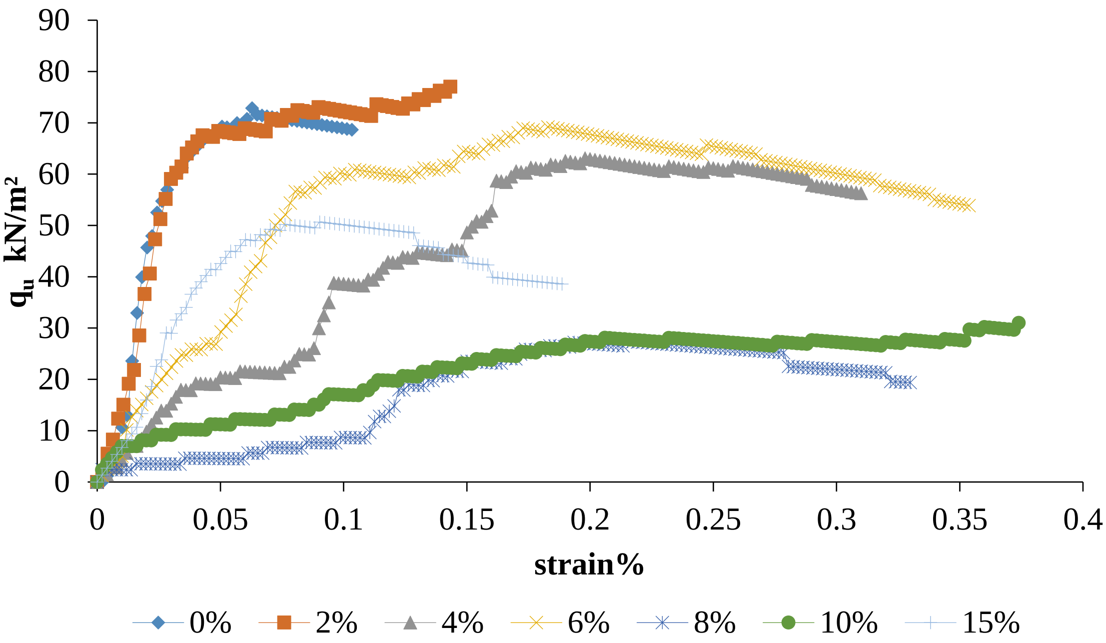


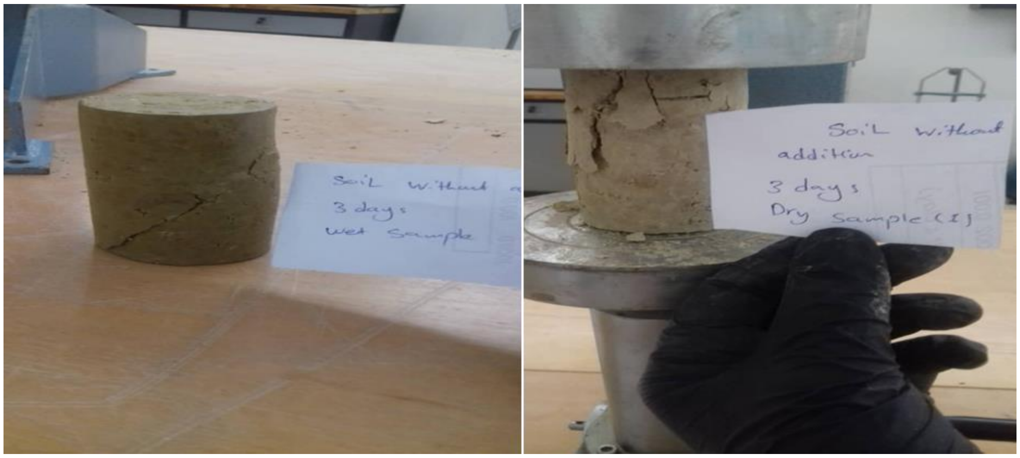
Fig. **10**.UCS of soil and soil-mixture in 3days (wet case)

Effects of Granulated Rubber content on Failure Patterns

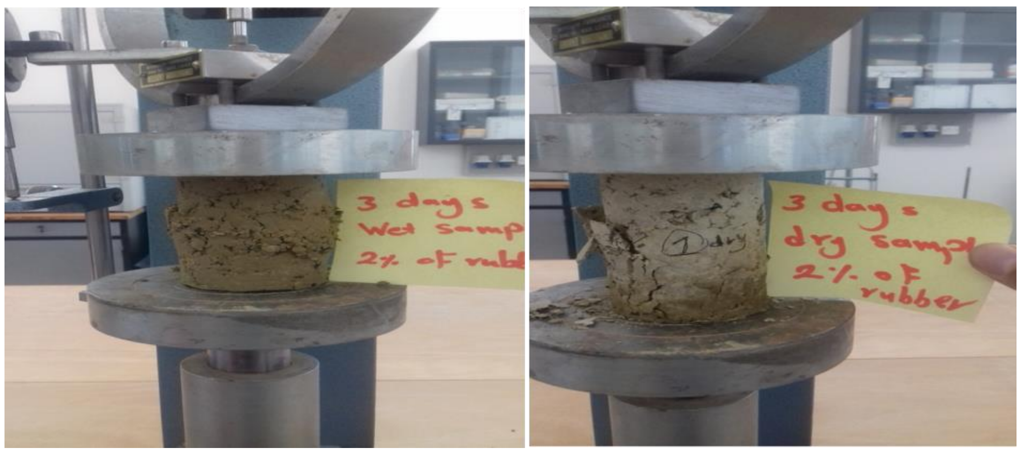
By observing the specimens during the UCS tests, it is seen that unreinforced specimens show cracks when vertical strains are very small and these cracks continue to grow until total failure. The Granulated Rubber reinforced specimens developed cracks much slower, as the bond stress between the Granulated Rubber and soil mixture played a role in postponing the crack development. An example of this is shown in Fig. 11, where Granulated Rubber reinforced specimen developed many small cracks and the stress level remained close to the peak stress. In the case of the unreinforced specimen shown, the stress level dropped significantly after reaching peak stress. It's concluded that GR may have influence on the failure modes of the mixtures effectively. This can be attributed to the elasticity of the rubber to reduce cracking, by forming a bridge between the soil particles

Conclusion

1. To reduce scrap and promote good cleaner production, we can repurpose damage in accordance with environmental safety compliance practices.
2. By using granulate rubber as stabilization a low- cost technique of stabilization is introduced and the problem of disposing of used tires is greatly alleviated.
3. The OWC value of soil mixed rubber increased with its add up to8, then declined when the amount of granulate rubber was increased.
4. The maximum unconfined compressive strength for clay soil in 3 days occurs when approximately 2% of granulate rubber tire was added



(a) Unreinforced soil



(b) 2% of Granulated Rubber

Fig. 11. Specimens at End of UCS Tests (a) unreinforced soil, (b) 2% of Granulated Rubber

Conflicts of Interest

The authors declare no conflict of interest.

List of Abbreviations

USCS Unified Soil classification system
Cc coefficient of curvature
CBR California bearing ratio
Cs swelling index
Cu coefficient of uniformity
W Natural moist content
MDD maximum dry density
OWC optimum water content
GR Granulated Rubber
G_s specific gravity of soil grains
L.L Liquid limit
P.L Plastic limit

PI Plastic index
LI Liquid index
CI Consistency index
UCS Unconfined Compression Strength

References

1. N. Ameta, D. Purohit, and A. S. Wayal, "Characteristics, problems and remedies of expansive soils of Rajasthan, India," EJGE, vol. 13, pp. 1-7, 2007.
2. A. K. Pathak, V. Pandey, K. Murari, and J. Singh, "Soil stabilisation using ground granulated blast furnace slag," Int.J.Eng.Res.Appl, vol. 4, pp. 164- 171, 2014.
3. Z. Nalbantoglu and E. Gucblimez, "Improvement of calcareus expansive soils in semi-arid environments," journal of arid environments, vol. 47, pp. 453-463, 2001.
4. A. F. Elhakim, M. j. Mohammed, and M. A. Elkhouly, "Improvement of expansive soil using granulated scrap tires," Innovative Infrastrcture Solutions, vol. 7, pp. 1-11, 2022.
5. Z. Nalbantoglu, "Effectiveness of class C fly ash as an expansive soil stabilizer," Construction and Building Materials, vol. 18, pp. 377-381, 2004.
6. A. Kumar, B. S. Walia, and A. Bajaj, "Influence of fly ash, lime,and polyester fibers on compaction and strength properties of expansive soil," Journal of materials in civil engineering, vol. 19, pp. 242-248, 2007.
7. M. s. Azam, A. k. Sharma, A. Agarwat, R. Verma, L. Singh, and N. Jee, "Altering the geotechnical properties of clayey soil by using scrap rubber," International Journal of Engineering Research & Technology,9(7), pp. 199-203, 2020.
8. D. Akbarimehr, E. Aflaki, and A. Eslami, "Experimental investigation of the densification properties of clay soil mixes with tire waste," Civil Engineering Journal, vol. 5, pp. 363-372, 2019.
9. D. Akbarimehr and E. Aflaki, "An experimental study on the effect of tire powder on the geotechnical properties of clay soils," Civil Engineering Journal, vol. 4, pp. 594-601, 2018.
10. M. Rahgozar and M. Saberian, "Geotechnical properties of peat soil stabilised with shredded waste tyre chips," Mires & Peat, vol. 18, 2016.
11. G. V. Rao and R. K. Dutta, "Compressibility and strength behaviour of sand-tyre chips mixtures," Geotechnical & Geological Engineering, vol. 24, pp. 711-724, 2006.
12. T. B. Edil and P. J. Bosscher, "Engineering properties of tire chips and soil mixtures," Geotechnical testing journal, vol. 17, pp. *453- 453, 1994*.
13. M. Saberian, M. Mehrinejad Khotbehsara, S. Jahandari, R. Vali, and J. Li, "Experimental and phenomenological study of the effects of adding shredded tire chips on geotechnical properties of peat," International Journal of Geotechnical Engineering, vol.12, pp. 347-356, 2018.
14. P. V. Sivapullaiah, T. G. Sitharam, and K. S. Rao, "Modified free swell index for clays," ASTM geotechnical testing journal, vol. 10, 1987.
15. A. Priyadarshee, D. Gupta, V. Kumar, and V. Sharma, "Comparative study on performance of tire crumbles with fly ash and kaolin clay," International Journal of Geosynthetics and Ground Engineering, vol. 1, pp. 1-7, 2015.
16. M. D. Ahmed and A. M. Adkel, "Stabilization of clay soil using tyre ash," Journal of Engineering, vol. 23, pp. 34-51,2017.
17. Y. Kim and H. Kang, "Engineering characteristics of rubber-added lightweight soil as a flowable backfill material," Journal of Materials in Civil Engineering, vol. 23, pp. 1289-1294, 2011.
18. S. Akbulut, S. Arasan, and E. Kalkan, "Modification of clayey soils using scrap tire rubber and synthetic fibers," Applied Clay Science, vol. 38, pp. 23-32, 2007.
19. F. Wang and W. Song, "Effects of Crumb Rubber on Compressive Strength of Cement-Treated Soil," Archives of Civil Engineering, vol.61, pp. 59-78, 2015.
20. K. Mukherjee and A. Mishra, "impact of scrapped tyre chips on the mechanical properties of liner materials," Environmental Processes, vol. 4, pp. 219-233, 2017.