Contents list available at: https://journals.ekb.eg/
Sohag Journal of junior Scientific Researchers
journal homepage: https://sjyr.journals.ekb.eg/
ISSN 2735-5543

*Article*

# Tire Waste Impact on Sandy Soil Behavior

**Ahmed Abdelraheem Farghaly[1], Fatma Hamdy[1,] *, Ahmed O. Mahmoud[2], A. El-Shater[3], and Mohamed Farid Abbas[4]**

[1]Department of Civil and Architectural Constructions, Faculty of Technology and Education, Sohag University, Sohag, 82524, Egypt
[2]Civil Engineering Department, Faculty of Engineering, Sohag University, Sohag, 82524, Egypt
[3]Department of Geology, Faculty of Science, Sohag University, Sohag, 82524, Egypt
[4]Soil Mechanics and Geotechnical Engineering Research Institute (on leave), Housing and Building National Research Center (HBRC), Giza, Egypt
*****Correspondence: hamasathaya@gmail.com ;

Article info

**Citation:** Farghaly, A. A.; Hamdy, F.; Mahmoud, A. O.; El-Shater, A.; Abbas, M. F.

**Title**. Tire Waste Impact on Sandy Soil Behavior

*SJYR* **2024**, *4*, 3. https://doi.org/10.21608/sjyr.2024.269402.1401

Academic Editor: Mohamed Kelany

Received: 05/03/2024
Accepted: 25/09/2024
Published: 01/12/2024

**Publisher's Note:** SJYR stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Abstract**

The population growth leads to an increase of transportation means, which is translated to an enlargement of scrap tires. Millions of scrap tires from around the world every year have been received. Hence, many environmental problems such as the potential of serious fires may occur. As well, the high cost of scrap tires dispose causes headache to municipals. Therefore, it is necessary to provide some solutions to this issue. Recycling this waste to be used as a sustainable material to improve the soil properties in construction projects such as building roads, retaining walls, and drainage systems is an ideal solution. The main aim of the current study is to compare the mechanical behavior of sandy soil mixed with rubber waste obtained from scrap tires in two forms: Fine Rubber (FR) and Coarse Rubber (CR). Tests were conducted with different rubber contents (0%, 5%, 10%). A noticeable change in soil properties was obtained after adding rubber to it. The percentage of 5% of coarse rubber is the percentage that has the best effect on the properties of the soil.

**Keywords:** California bearing ratio; Consolidation; Shear strength; Fine Rubber (FR); Coarse Rubber (CR).

## 1. Introduction

Soil is considered the lowest element present in the earth's crust, and it is one of the oldest methods used in construction (BRAJA M. DAS, 2009). Sandy soil is known as non-cohesive soil or frictional soil because there is no interaction between its particles. Non-cohesive soils are characterized by low shear strength, low bearing capacity, high permeability, and no flexibility, and the shear stress between their particles is small or non-existent (Al-Saray et al., 2021). Today, there is a worldwide interest in sustainable factors, which attracted investigators to create alternative materials that fulfill design criteria. Soil stabilization is often used to enhance soil properties by additions (Alhassani, 2021)**.** Soil properties can be improved and stabilized by changing their geotechnical properties including shear strength, plasticity, fluidity, consistency, and permeability to produce improved soil. The improvements of soil stabilization include improving soil resistance, hardness and durability and reducing soil elasticity, swelling or shrinkage (Seo et al., 2021)**,** (Kore & Vyas, 2016). Soil additives are used to reduce the permeability and compaction of the soil and increase its strength in case of weak soil and to improve its properties (Rossiter, 1997).

Waste materials cause a lot of environmental problems and economic problems. To mitigate these problems, it is required to find safe ways to decrease its harm to the environment and on the economy. Waste tire aggregates in mixtures with sand have been used in recent years as an alternative. To be exploited to reduce seismic response of foundations (Tsiavos et al., 2019), (Mikayel Melkumyan, 2020), (Hing-Ho Tsang et al., 2012). The complexity of tires composition prevents the recycling process and recycle 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 (Al-Neami, 2018). Due to the large quantities of the used car tires that are disposed of every year, a lot of research have been conducted to study the effect of using recycled rubber in concrete mix tires, where it was obtained Mixing crumb rubber increases shock resistance and hardness. On the other hand, the modulus of elasticity and the modulus of rupture and splitting Tensile strength decreases when crumb rubber is introduced into the concrete mixture (Park et al., 2016)**.** Using rough rubber or tire waste is a modern method to improve soil properties (Lopera Perez et al., 2016), (Liu et al., 2022). Used tires contain fibers, steel belts and tread rubber as the three main components. Tires are essential for mobility, and essential for vehicle safety (Araujo-Morera et al., 2021). Rubber granules were added in proportions of 0%, 5%, 10%, 15%, 20% and 30% by weight. The samples were tested under a confining pressure of 100 kPa. The results showed that the shear strength of the mixtures increased uniformly as the percentage of rubber in the mixtures increased to 30%. The improvement in shear strength increases with increasing relative density and increasing friction angle, and the best rubber percentage is between 10% and 20% (Negadi Kheira & Ahmed, 2019). Other previous studies carried out in several laboratories have shown that increasing the rubber content in sand decreases the shear strength of the mixture (Benjelloun et al., 2021). The effect of rubber on some engineering properties of sandy soils, such as cohesion value and CBR value was studied. Adding rubber granules to the sand in proportions from 0% to 20% of rubber. It was obtained that the shear strength of the mixtures increased first and then decreased with an increase in the granulated rubber content by 10% (Ding et al., 2021). *Deepti V. Zutting* conducted a set of experiments on sand samples with different proportions of dune sand rubber crumbs. Various sand crumb rubber mixtures containing 0%, 5%, 10%, 15%, 20%, 25%, and 30% of waste crumb. Rubber particles were selected by sand weight. To determine the effect of rubber waste on shear strength, a direct shear tester was used. It has been found that adding up to 20% crumb rubber to sand dunes significantly increases shear strength coefficients: Cohesion and angle of internal friction (Deepti V. Zutting, 2020). Used rubber tire fibers were used to strengthen the soil, tests were conducted Proctor test, triaxial test, and CBR test with ratios 2.5%, 5%, 7.5%, and 10% by weight. It is found that the MDD of reinforced soil increases, and OMC decreases when Sand Coated Chopped Rubber Tire Fiber (SCCRTF) is used as reinforcement instead of Un-Coated Chopped Rubber Tire Fiber (UCCRTF). When the soil was mixed with UCCRTF the internal friction angle (ϕ) increased from 5 to 18 Soil cohesion (Singh & Garg, 2019).

## 2. Materials and Methods

In this study, Soil samples were obtained from Sohag Governorate – Egypt. Particle size distribution analysis was performed, and the soil was classified as poor graded sand as per Unified Soil Classification System (USCS). In this study, Fine Rubber (FR) and Coarse Rubber (CR) waste of tires have been used, Figure 1, and added to the selected sandy soil to enhance its behavior. The experimental program involved compaction, CBR and consolidation testing, which were carried out for sand with different percentages of two kinds rubber explained in Table1.


**Figure 1.** Various Rubber was used for this study.

**Table 1.** Designations for the various mixtures sand-Rubber.

| Designations | Sand-Coarse Rubber | Designations | Sand-Fine Rubber |
|---|---|---|---|
| CR0 | 100% Sand + 0% Coarse Rubber | FR0 | 100% Sand + 0% Fine Rubber |
| CR5 | 95% Sand + 5% Coarse Rubber | FR5 | 95% Sand + 5% Fine Rubber |
| CR10 | 90% Sand + 10% Coarse Rubber | FR10 | 90% Sand + 10% Fine Rubber |

## 3. Experimental Examination

The compaction test was conducted on natural soil and soil with rubber added in both cases in order to determine Compression characteristics (OMC and MDD) by Proctor standard test.

CBR is one of the important tests in pavement design to determine the thickness of the pavement. Hence, CBR tests were performed on both untreated soils, soil mixtures, and crumb rubber powder. Initially, soil samples were prepared according to maximum dry density and optimum moisture content. The penetration rate used was 1.25 mm/min. Values of loads causing penetration of 2.5 mm and 5 mm were recorded andthe highest value was taken (Ravichandran et al., 2016).

Consolidation is the process of reduction in volume due to the expulsion of water under an increased load. Terzaghi was the pioneer who first suggested the one-dimensional technique for testing consolidation. This test is conducted in a consolidometer, also known as an odometer. The soil sample is put inside a metal ring that has two porous stones in it: one at the top and one at the bottom. The specimens typically have a diameter of 75 mm and a thickness of 25 mm. A micrometer dial gauge is used to measure compression when a lever arm applies the force to the specimen. Throughout the test, the specimen is submerged in water. Subsequently, the load is often doubled, resulting in a doubling of the specimen's pressure, and the compression measurement proceeds (BRAJA M. DAS, 2009; Egyptian Code, 2007).

## 4. Results and Discussion

4.1. Standard proctor test results

Two percentages of rubber were used 5% and 10% from weight of soil. The relationship between dry density on the Y axis and moisture content on the X axis was plotted for both CR and FR. The maximum dry density and optimum moisture content were obtained and listed in Table 2. The OMC decreased for both series with increase the rubber content. With respect to the MDD, increase the coarse rubber content resulted in reduction in MDD, while the fine rubber has no impact on its MDD.

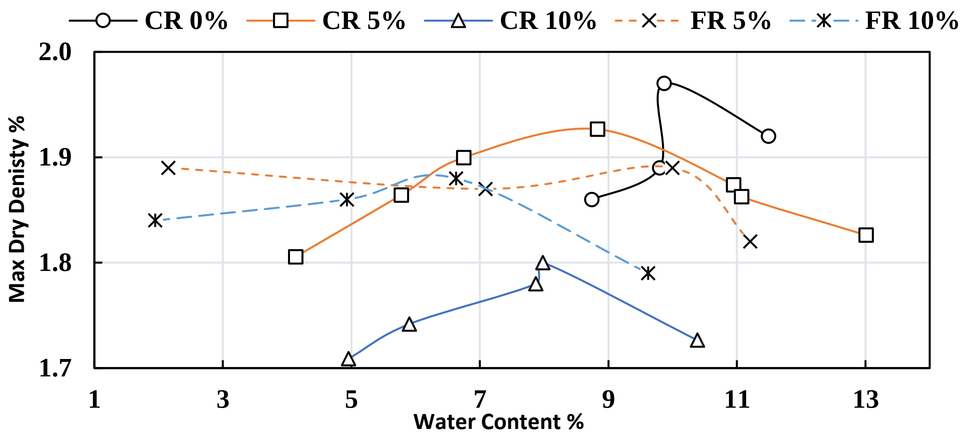


**Figure 2.** Combined compaction response curve of sandy soil with addition CR-FR.

**Table 2.** Results of Proctor test

| CR series | OMC (%) | MDD (g/cc) | FR | OMC (%) | MDD (g/cc) |
|---|---|---|---|---|---|
| CR0 | 9.87 | 1.97 | FR0 | 9.87 | 1.97 |
| CR5 | 8.83 | 1.93 | FR5 | 8.20 | 1.92 |
| CR10 | 7.98 | 1.8 | FR10 | 7.83 | 1.86 |

Figure3. presents addtion of FR, CR As the percentage of rubber increases, the optimum moisture content and the maximum dry density decreases.

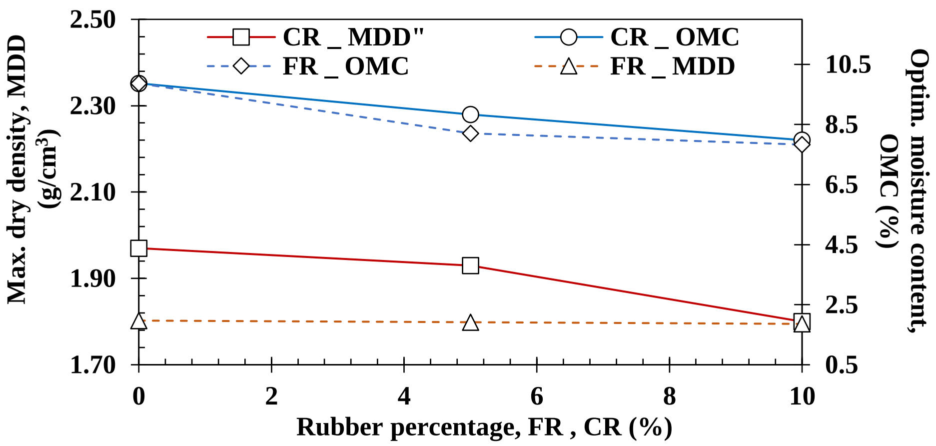


**Figure 3.** OMC and MDD versus percentage of FR- CR.

4.2 Un- Soaked CBR Test Results

After applied CBR test graphs were plotted between Load versus penetration as presents in Figure 4. For FR and CR mixed soil, table 3 presents the values of CBR. Figure 5. presents Increasing percentage of FR and CR decrease the CBR value.

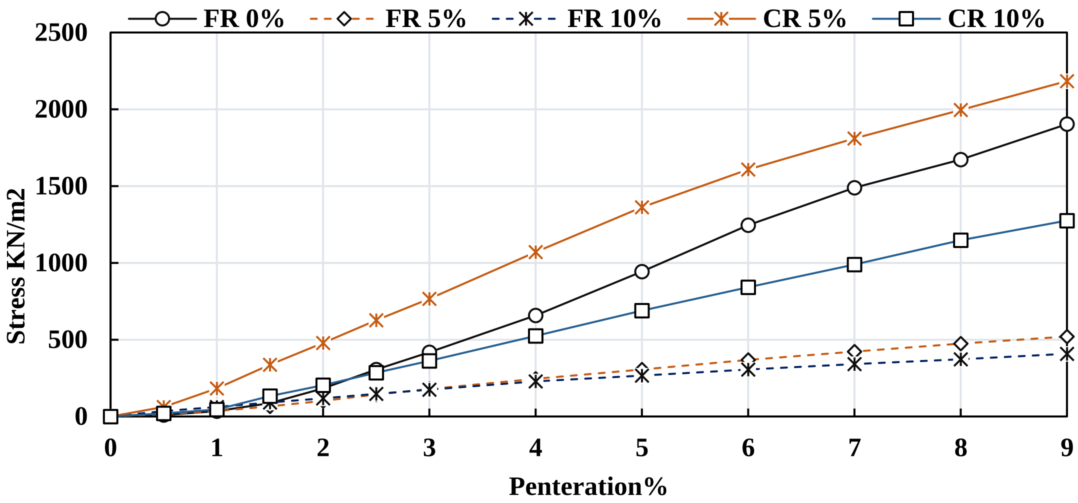


**Figure 4.** Load verses Penetration Curve of CBR Test for different proportion of FR- CR

**Table 3.** Results of CBR

| Percentage % | CR, CBR% | FR, CBR% |
|---|---|---|
| Virgin Soil | 13.79 | 13.79 |
| 5% | 13.59 | 3.33 |
| 10% | 7.77 | 2.57 |

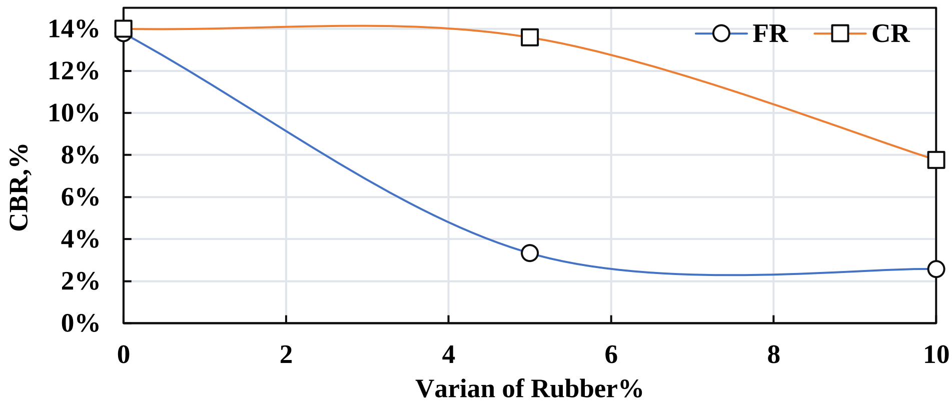


**Figure 5.** Variation of CBR Value with different proportion of FR-CR

4.3 Consolidation Test Results

After applied Odomter test graphs were plotted between Load versus FR, CR % and Void Ratio as presents in Figure 6, the consolidaion is increasing by increase percentage of FR and CR.

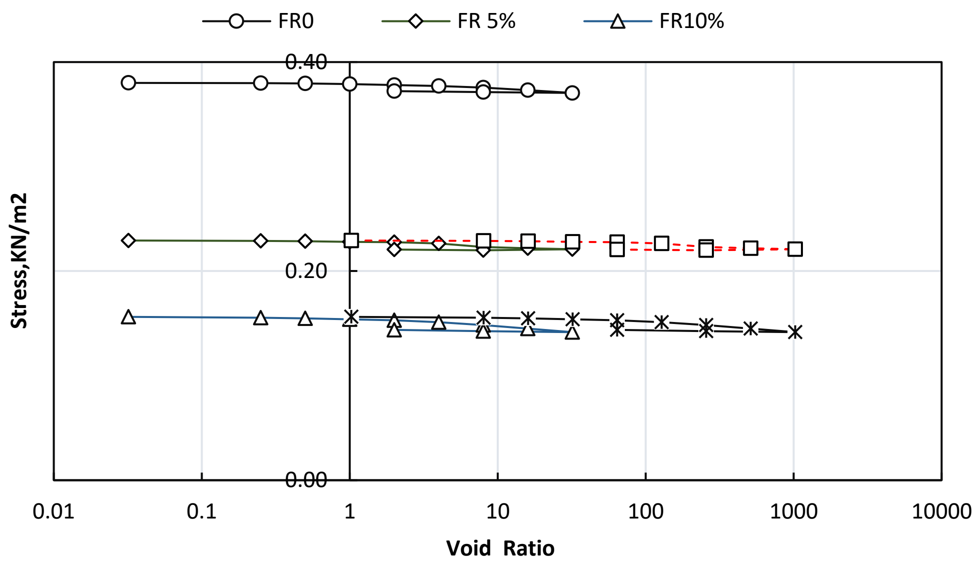


**Figure 6.** Variation of Stress and Void ratio of with different proportion of FR- CR

## 5. Conclusions

The use of recycled tire waste does not have a significant role in improving the engineering properties of the type of poorly classified sand used. The following conclusions can be drawn: -

1. Rubber was added between 5% and 10% of the soil weight.
2. The FR and CR formula reduces the Maximum dry density and reduces the optimum moisture content in the standard Proctor test.
3. Decreasing in the percentage of CBR was observed by increasing percentage of FR and CR.
4. Decreasing in the strength was observed by increasing percentage of FR and CR.

## References

Al-Neami, M. A. (2018). Stabilization of sandy soil using recycle waste tire chips. *International Journal of GEOMATE*, *15*(48), 175–180. https://doi.org/10.21660/2018.48.180228

Al-Saray, N. A., Shafiqu, Q. S., & Ibrahim, M. A. (2021). Improvement of strength characteristics for sandy soils by polypropylene fibers (PPF). *Journal of Physics: Conference Series*, *1895*(1). https://doi.org/10.1088/1742-6596/1895/1/012016

Alhassani, A. M. J. (2021). Improvement of sandy soil using materials of sustainable consideration. *Jordan Journal of Civil Engineering*, *15*(4), 623–632.

Araujo-Morera, J., Verdejo, R., López-Manchado, M. A., & Hernández Santana, M. (2021). Sustainable mobility: The route of tires through the circular economy model. *Waste Management*, *126*, 309–322. https://doi.org/10.1016/j.wasman.2021.03.025

Benjelloun, M., Bouferra, R., Ibouh, H., Jamin, F., Benessalah, I., & Arab, A. (2021). Mechanical behavior of sand mixed with rubber aggregates. *Applied Sciences (Switzerland)*, *11*(23). https://doi.org/10.3390/app112311395

BRAJA M. DAS. (2009). *Principles of Foundation Engineering, SI*.

Deepti V. Zutting. (2020). Soil Stabilization by using Scrap Tire Rubber. *International Journal of Engineering Research And*, *V9*(06), 1382–1388. https://doi.org/10.17577/ijertv9is060592

Ding, Y., Zhang, J., Chen, X., Wang, X., & Jia, Y. (2021). Experimental investigation on static and dynamic characteristics of granulated rubber-sand mixtures as a new railway subgrade filler. *Construction and Building Materials*, *273*, 121955. https://doi.org/10.1016/j.conbuildmat.2020.121955

Egyptian Code. (2007). *Egyptian Code of Soil Mechanics, Foundations Carrying out and Designation, Part 2, Laboratory Tests (ECP 202-2001)* (6th Editio).

Hing-Ho Tsang, M. Neaz Sheikh, S.H.Lo, & X.Xu. (2012). *Seismic isolation for low-to-medium-rise buildings using granulatedrubber–soil mixtures: numerical study*.

Kore, S. D., & Vyas, A. K. (2016). Impact of marble waste as coarse aggregate on properties of lean cement concrete. *Case Studies in Construction Materials*, *4*, 85–92. https://doi.org/10.1016/j.cscm.2016.01.002

Liu, F. yu, Fu, J., Wang, J., Gao, Z. yang, Li, H. ze, & Li, J. ting. (2022). Effect of the particle size ratio on macro- and mesoscopic shear characteristics of the geogrid-reinforced rubber and sand mixture interface. *Geotextiles and Geomembranes*, *50*(4), 779–793. https://doi.org/10.1016/j.geotexmem.2022.04.002

Lopera Perez, J. C., Kwok, C. Y., & Senetakis, K. (2016). Effect of rubber size on the behaviour of sand-rubber mixtures: A numerical investigation. *Computers and Geotechnics*, *80*, 199–214. https://doi.org/10.1016/j.compgeo.2016.07.005

Mikayel Melkumyan. (2020). The Use of High Damping Rubber Isolators to Upgrade Earthquake Resistance of Existing Buildings in Armenia. *International Post-SMiRT Conference Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control of Seismic Vibrations of Structures*, *May*, 861–867.

Negadi Kheira, & Ahmed, A. (2019). *A Direct Shear Investigation on the Determination of the Shearing Resistance of Reinforced Soil with Waste Rubber* (Issue January).

Park, Y., Abolmaali, A., Kim, Y. H., & Ghahremannejad, M. (2016). Compressive strength of fly ash-based geopolymer concrete with crumb rubber partially replacing sand. *Construction and Building Materials*, *118*(2016), 43–51. https://doi.org/10.1016/j.conbuildmat.2016.05.001

Ravichandran, P. T., Prasad, A. S., Krishnan, K. D., & Rajkumar, P. R. K. (2016). Effect of Addition of Waste Tyre Crumb Rubber on Weak Soil Stabilisation. *Indian Journal of Science and Technology*, *9*(5). https://doi.org/10.17485/ijst/2016/v9i5/87259

Rossiter, D. G. (1997). CHAPTER 9 Soil for Stabilization and Airfields Roads Section I . Methods of Stabilization. *Faculty of Geo-Information Science and Earth Observation of the University of Twente*, 1–81.

Seo, S., Lee, M., Im, J., Kwon, Y. M., Chung, M. K., Cho, G. C., & Chang, I. (2021). Site application of biopolymer-based soil treatment (BPST) for slope surface protection: in-situ wet-spraying method and strengthening effect verification. *Construction and Building Materials*, *307*(April), 124983. https://doi.org/10.1016/j.conbuildmat.2021.124983

Singh, D., & Garg, P. (2019). *STUDY OF SAND COATING ON WASTE*. *06*(1), 550–556.

Tsiavos, A., Alexander, N. A., Diambra, A., Ibraim, E., Vardanega, P. J., Gonzalez-Buelga, A., & Sextos, A. (2019). A sand-rubber deformable granular layer as a low-cost seismic isolation strategy in developing countries: Experimental investigation. *Soil Dynamics and Earthquake Engineering*, *125*(May), 105731. https://doi.org/10.1016/j.soildyn.2019.105731

مقال أصلي

## الملخص العربي

# تأثير نفايات إطارات السيارات على سلوك التربة الرملية

أحمد عبد الرحيم [1]، فاطمة حمدي[1،*] ، أحمد عمر[2]، عبد الحميد الشاطر [3،*]، محمد فريد عباس [4]

[1] قسم الانشاءات المدنية والمعمارية، كلية التكنولوجيا والتعليم، جامعة سوهاج، سوهاج 82524 ، مصر
[2] قسم الهندسة المدنية، كلية الهندسة، جامعة سوهاج، سوهاج 82524 ، مصر
[3] قسم الجيولوجيا، كلية العلوم، جامعة سوهاج، سوهاج 82524 ، مصر
[4] معهد ميكانيكا التربة والهندسة الجيوتكنيكية، المركز القومي لبحوث الاسكان والبناء، الجيزة، مصر

[*]فاطمة حمدي: hamasathaya@gmail.com

تؤدى مشكلة النمو السكاني إلى زيادة استخدام وسائل النقل والمواصلات، وهو مايؤدى إلى زيادة نفايات الاطارات حيث يتم الحصول على ملايين من هذه النفايات سنوياً فى جميع أنحاء العالم. التى قد تسبب العديد من المشاكل البيئية مثل الحرائق والتلوث البيئى والبصرى ...الخ. التخلص من هذه النفايات يحتاج الى تكلفة اقتصادية عاليه. الحل الامثل لهذه المشكلة اعادة تدوير هذه النفايات لاستخدامها كمواد مستدامة لتحسين خصائص التربة في مشاريع البناء مثل بناء الطرق، الحوائط السانده، وأنظمة الصرف الصحي. الهدف الرئيسي من هذه الدراسة هو مقارنة السلوك الميكانيكي للتربة الرملية المدعمه بالمخلفات المطاطية والتى تم الحصول عليها بعد اعادة تدوير مخلفات الاطارات. تم استخدام احجام مختلفه من المطاط: المطاط الناعم (FR) والمطاط الحرش (CR). تم إجراء العديد من الاختبارات لحساب الهبوط وتحديد نسبه تحمل كاليفورنيا بنسب مطاطية مختلفة (0%، 5%، 10%)من وزن التربة الطبيعية .اظهرت النتائج تغير ملحوظ في خواص التربة بعد إضافة المطاط إليها. نسبة 5% من المطاط الحرش هي النسبة التي لها أفضل تأثير على خواص التربة.

**الكلمات المفتاحية**: المطاط الحرش؛ المطاط الناعم؛ نسبة تحمل كاليفورنيا؛ الهبوط؛ مقاومة القص.