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Utilization of Waste plastic in Geotechnical Engineering Applications in Iraq: A Review

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Article Info.	Abstract
<p><i>Article history:</i></p> <p>Received 18 June 2021</p> <p>Accepted 06 November 2021</p> <p>Publishing 31 December 2021</p>	<p>Plastic waste is accumulating with the progression of time, posing significant difficulty around the world. As a result, effective solutions to environmental concerns are required. There is also another issue, which is that projects frequently encounter weak soil, which must be modified. The purpose of this paper is to conduct a comprehensive study of the literature in order to compile information on utilization of waste plastic in geotechnical engineering applications specially in soils stabilizing. This article summarizes the local researches that is done in this topic to determine the use of waste plastic as material for reinforcing soil in Iraq. According to the outcomes of this study, plastic waste can be utilized as an eco-friendly and cost-effective way to improve the strength of the soil. It has been discovered that adding (0.5-4) wt. % plastic waste to a property improves its value. In terms of additive dimensions, it was explored that plastic waste with a greater aspect ratio produced greater test results. Finally, when compared to non-stabilized samples, compaction parameters, shear strength parameter, and CBR (California bearing ratio), of stabilized samples were significantly enhanced.</p>

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1. Introduction

Soil is an essential building element that is operated in a variety of ways. Most construction works are built on foundations that are essentially earth. Any land-based system's foundation is crucial, and it must be strong in order for the system to operate effectively. The soil around it is extremely important in ensuring a solid foundation. To work with soils, we must have a thorough understanding of their properties and the elements that influence their behavior. The soil stabilization method aids in obtaining the precise qualities required for work of building in an earth. The significance of enhancing the qualities of soil has been recognized since the beginning of construction [1,2].

Soil stabilization is the method of enhancing the engineering characteristics and increasing the stability of a soil. Soils are frequently stabilized to increase their performance and toughness, as well as to prevent erosion and dirt. The main objective is to find a soil component or technique that will stand up for the engineering project during construction and for the life of the structure, the essential conceptions of soil stabilization are: evaluating the soil properties, determining the lack of soil characteristics, selecting an efficient and cost-effective type of soil stabilization, and developing a stabilized soil mix for the desired stabilization and stability qualities [3–5] There are two kinds of soil stabilization methods: mechanical and chemical. Mechanical stabilization involves combining existing soil with introduced soil or aggregate to get the required particle size distribution and compressing the mixture to the required density [6]. Compaction of a soil to a desired moisture content is a mechanical stabilizing approach in and of itself [7,8] Chemical stabilization comprises addition or inserting substances for instance lime, sodium silicate, asphalt, bituminous materials, calcium chloride, bituminous materials, and resinous compounds with or in the soil can help to improve its stability. Chemical stabilization is a broad phrase that refers to the employment of chemicals in order to achieve stability [9–11].

The extensive usage of single-use plastics in everyday consumer applications continues to contribute to an even more volume of plastic material deposited in municipal solid trash in Iraq and around the world. Landfills are frequently filled with recycled debris that has only been used for

a short time, with more than half of the plastics disposed coming from packaging products [12,13] With landfills rapidly filling up, finding a resolution to this non-biodegradable plastic waste is critical to achieving an ecological environment. Also there are environmental concerns across the world, therefore using waste materials for soil stabilization is a good idea because it reduces waste and stabilizer costs [14,15] Since civil engineering applications require huge amounts of resources, reprocessing potential waste and recyclable materials in place of normal raw materials is advantageous because it minimizes natural resource demand [16–19] One of the finest ways for enhancing the soil's engineering characteristics and managing the volume of plastic waste is to employ this plastic waste to develop the soil's engineering capabilities by strengthening soil with plastic shreds in geotechnical applications [20,21]. Any stabilization approach tries to increase soil strength, resilience, workability, erosion controlling, and buildability. Instead of scraping and substituting the material, stabilization for any particular soil might improve the soil qualities [22].

Despite rapid technological advancements on a global scale, the usage of plastics such as plastic bags, bottles, and other containers is increasing. Every year huge amount of plastic used in Iraq [12], [23,24]. Threw plastic disposal is a big issue as utmost plastic waste is non-biodegradable and unsuited on behalf of combustion due to harmful gas emissions [25–27] Accomplished compaction or the use of stabilizing materials for example asphalt, lime, or other additions improve the engineering properties of a weak soils, although these chemicals have become increasingly expensive in recent years [28–30] utilization of waste plastic in soil stabilization consider as solution of this statement by; offering a different way of disposing of plastic waste, providing an economical solution for soil stabilization by consuming plastic waste. Waste is harmless, just required to be reprocessed, it is eco-friendly; thus, it will preserve the environment, and reducing soil compressibility to rise tensile strength and shear resistance of the treated soil.

The aim of this research is to conduct a literature research, that conducted by local researchers, in order to determine the efficacy of plastic waste in enhancing soil qualities and whether they are worthwhile to use. Also, to identify appropriate percentages and dimension for later use in other research, which will make the process of determining the best dimension and percentages easier.

2. Literature Review

Several experiments on soil stabilization using plastic waste have been carried out by locally researchers in recent years. Some of them are discussed in succeeding paragraphs and summarized in Table 1.

Nsaif, 2013 [31] investigated the influence of adding plastic waste (recycled polyethylene) to clayey and sandy soils at four fractions (2%, 4%, 6%, and 8%) by soil weight for each type of soil. The used recycled polyethylene plastic waste with cylindrical shape have diameter 1to 2 mm and height 5 mm. two parameters of shear strength (angle of internal friction and cohesion value) were examined by direct shear test for both type of soil, also compaction test was conducted for clayey soil. the experimental outcomes revealed that the insertion recycled polyethylene plastic waste increase the angle of internal friction with increasing the plastic ratio, however, cohesion value for both soils slightly effected. The increment in angle of internal friction for sandy soil are 13.5 %, 21.6% 40.5, and 48.6 for waste plastic fractions 2%, 4%, 6%, and 8% respectively, when compared with unreinforced sandy soil. The increment in angle of internal friction for clayey soil are 14.3 %, 19.0% 42.8, and 52.4 for waste plastic fractions 2%, 4%, 6%, and 8% respectively, when compared with unreinforced clayey soil.

Alshkane, 2017 [32] conducted an experimental study on the effect of the utilization of waste plastic fibers on the shear strength of sandy soil. The waste plastic fibers were prepared from polyethylene terephthalate bottles shredded into fibers with two lengths 8 mm and 16 mm. The waste fibers for each length were added to sandy soil at three percent (1,2, and 4) % by weight, and then the two parameters of shear strength (angle of internal friction and cohesion value) were inspected by direct shear test. The insertion of waste plastic fibers increased both angle of internal friction and cohesion. For example, the increase percentage in angle of internal friction at (1, 2, and 4) % long plastic fibers are about (8, 12, and 16) % when compared with soil without plastic, respectively. The increase percentage in cohesion value at (1, 2, and 4) % long plastic fibers are (20, 115, and 240) % when compared with soil without plastic, respectively.

Salim et al., 2018 [33] utilized arbitrarily shredded plastic waste-based ethylene into different aspect ratio for strengthening the clayey soil collected from Baghdad. Three percent of plastics waste were selected (1 %, 2%, 4 %) by the weight of the dry soil and compared with soil without plastic. The measured soil properties were specific gravity, California bearing ratio, unconfined compressive strength, and Atterberg limits. The outcomes demonstrated that the addition of the plastic waste significantly effect on the modified clayey soil. The specific gravity decrease as percentage of waste plastic increases. The decrement of the specific gravity for 1%, 2%, and 4% plastic waste were approximately 6%, 11%, and 15 % when compared with soil without plastic, correspondingly. The California bearing ratio increase as percentage of waste plastic increases. The increment of the California bearing ratio for 1%, 2%, and 4% plastic waste were approximately 55 %, 105 %, and 200 % when compared with soil without plastic, correspondingly. The unconfined compressive strength increase as percentage of waste plastic increases. The increment of the unconfined compressive strength for 1%, 2%, and 4% plastic waste were approximately 42 %, 83 %, and 180 % when compared with soil without plastic, correspondingly. The liquid limit decrease as percentage of waste plastic increases. While, plastic limit increase as percentage of waste plastic increases. The decrement of the liquid limit was 2%, 11 %, and 15 %. While, the increment of plastic 4%, 8 %, and 16 for 1%, 2%, and 4% plastic waste when compared with related value of soil without plastic.

In another study accomplished by Salim et al., 2018 [34] investigated the utilization of shredded nylon carry bags at various fractions (1, 3, and 5) % by weight of dry soil for enhancing of Baghdad soft clayey soil. Soil characteristics like, specific gravity, unconfined compressive strength, and Atterberg limits were examined for strengthened and un-strengthened soil. The results confirmed that the insertion of the shredded nylon carry bags considerably influence on the clayey soil characteristics. The reduction in the specific gravity of clayey soil ranged between (4- 10) % when compared to soil without nylon plastic. The unconfined compressive strength increase as percentage of waste plastic increases. The increasing in the unconfined compressive strength of clayey oil ranged between around (44 -130) % when compared to soil without nylon

plastic. The liquid limit decrease as percentage of waste nylon plastic increases. While, plastic limit increase as percentage of waste nylon plastic increases. The reduction percent of the liquid limit ranged about from (8-21) % when compared to soil without nylon plastic. However, the increasing percent of plastic limit ranged about from (6 - 28) %.

Irshayyid and Fattah, 2019 [35] investigated the behavior of expansive soil (80% clay + 20 % sand) with addition of waste plastic based of high-density polyethylene at fractions (4, 8, and 12) wt. % of dry soil. The results exhibited that the waste plastic fibers considerably enhanced the properties of expansive soil. The liquid limit values reduced as the plastic percent increase, while the plastic limit increased. The reduction percent of the liquid limit ranged from (8.5 -11.5) %, and the rising percent of plastic limit ranged from (26.4 - 81.2) %. Also, the unconfined compressive strength increase as the percent of waste plastic increase. the growing percent ranged about (13- 100) %.

Al-Taie et al. 2019 [36] implemented experimental study on the influence the insertion of depolymerized waste polyethylene terephthalate on the sandy soil. The waste plastic was shredded to (3×3) mm chips, then depolymerized to fine powder, and finally, added to sandy soil at various percent (0.5, 1.0, 1.5, and 2) wt.%. The test results exhibited that the properties of the sandy soil improved by the addition of depolymerized waste plastic. The improvement of the angle of internal friction reached to about 30 % for addition percent 2 % of plastic percent when compared with sandy soil without plastic. Also, the soil compression of plastic treated soil enhanced considerably.

Al-Neami et al. 2020 [37] inspected the opportunity of utilizing polypropylene waste fibers to improve the cohesive clayey soil. Three different length of plastic fibers (6, 12, and 18) mm were separately added to soil at different percentage (0.25, 0.5, and 0.75 %) by dry weight of soil. The experimental results exhibited that the reinforcing of soil by polypropylene fibers considerably improved the unconfined compressive strength and shear strength, also, the length of plastic fibers has an appreciable effect. The increase in cohesion value as shear parameter reached around 40 %, 70 %, and 100% for 6, 12, 18 mm fibers length related to native soil, respectively. The increase in the unconfined compressive strength parameter reached around 32 %, 47%, and 64 % for 6, 12, 18 mm fibers length related to native soil, respectively.

Kadhum and Aljumaili, 2020 [38] studied the application of plastic waste on the properties of subbase soil containing powder of ceramic waste. Domestic plastic waste was shredded to strips with dimensions (12 ×8) mm, and then added to subbase soil containing optimum ceramic waste at various fractions ranged from (0.25 - 1.0) wt. % of dry soil. They stated that the California bearing ratio value increased with increasing the percent of plastic waste. The maximum increment reached about 18 % for 1 % plastic waste strips compared with soil without plastic.

Hassan et al. 2021 [39] achieved a research involved investigation on stabilizing clayey soil by using plastic waste fibers prepared from polyethylene bottles and polypropylene bags. Fibers were used have two lengths 10 mm and 20 mm; the width ranged from 2.5 mm to 3 mm. Four percentages of waste plastic fibers were added to reinforcing the soil (1, 2, 3, and 4) wt. % of dry soil for length and type of fibers. The experimental work was included, unconfined compressive test, compaction test, and California bearing ratio. The results revealed that utilization of waste plastic fibers considerably enhanced the properties of clayey soil and the long fibers better than short, also, the polyethylene fibers slightly better than polypropylene fibers. The increasing present in unconfined compressive for polyethylene fibers was ranged from (76.4 - 63.5) % for 10 mm fiber length and ranged from (96.6 - 86.5) % for fibers content (1- 4) %, respectively. The increasing present in unconfined compressive for polypropylene fibers was ranged from (57.4 - 48.6) % for 10 mm fiber length and ranged from (73.0 - 65.5) % for fibers content (1- 4) %, respectively. The increment in California bearing ratio for polyethylene fibers was ranged, from (22.5 - 55.0) % for short fibers and, from (35.0 - 80.0) %, for (1- 4) % percent addition. Likewise, the increment for short polypropylene fibers ranged from (5 .0 - 42.5) % and for long polypropylene fibers from (20.0 - 50.0) %.

Fadhil et al.,2021 [40] conducted experimental work involved a series of unconfined compression tests on a sand-clay soil (60 % sand + 40 % clay) with / without adding waste plastic. The parameters of the study involved shape (plain and corrugated), length (5, 10, and 15 mm), width (1, 2, and 3) mm, and present of waste plastic addition (0.25, 0.5, 0.75, and 1.0) %. In general, the utilization of the waste plastic improved the unconfined compressive strength. The maximum increment in the unconfined compression strength obtained for (1×15) mm fibers at 1% plastic addition was about 181 % and 270 % for plain and corrugated, respectively.

Jaber et al., 2021 [41] evaluated the outcome of addition plastic waste on the strength properties of subbase. Five fractions of recycled polyethylene terephthalate plastic granule with cylindrical shape, 2.5 diameter and 4 mm height, the fractions ranged 2.5 to 12.5 % by volume (equivalent for near 1 to 4 % by weight). The results specified that the insertion of plastic waste granule significantly altered the performance of subbase. The increasing present in California bearing ratio for waste plastic granule was ranged from (6 - 36) %. They recommend 10 % of addition waste plastic granule.

Hameed et al. ,2021 [42] directed an experimental study on the influence of application of the waste plastic fibers on the performance of lime stabilized sandy soil. plastic fibers originated from low density polyethylene waste were utilized with different length (5, 10, and 20) mm, at various percent of addition (1, 2, and 3) % wt. of the soil. The results demonstrated that addition 10 cm length waste plastic fibers at 3% content produced a reduction in the surface deflection around 21 % and an increase in the dynamic modules of about 28 % as compared to soil without plastic.

The main advantages of using waste plastic in soil upgrading can be summarized: rise in the soil shear strength, improvement in the California bearing ratio, reduction in the soil permeability, upgrading in load bearing capacity, enhancing in the durability of soil, lessening in swelling and cracks, supports in consuming the waste plastic, obtainable in large quantity, and cost effective for improving the soil quality[43]–[45]

Table 1 Properties of different soils with various types of waste plastic

Reference	Type of treated soil	Waste plastic		Properties of treated soil (+ increment %, – decrement %)							
		Type	Add. % by wt.	Maxi. Dry Density	Optimum Moisture Content	California bearing ratio	Unconfined compressive strength	Shear strength	Plasticity index	Plastic limit	Liquid limit
Nsaif , 2013 [31]	sandy	Polyethylene pieces	2,4,6,8	--	--	--	--	+13 to 48	--	--	--
	Clayey			-2 to -7	-2 to -6	--	--	+14 to 52	--	--	--
Alshkane, 2017 [32]	Sandy	polyethylene terephthalate fibers	1,2,4	-6 to -15	---	---	--	+20 to +240	--	--	--
Salim <i>et al.</i> , 2018 [33]	clayey	Ethylene strips	1,2,4	-5 to -11	-2.3 to -7.5	+55 to +200	+42 to +180	+45 to +175	-9 to -50	+4 to +14	-2 to -15
Salim <i>et al.</i> , 2018 [34]	clayey	shredded nylon	1,3,5	-5 to -11	+0 to +33	--	-30 to -38	+45 to +136	-25 to -70	+5 to +25	-8 to -21
Irshayyid and Fattah , 2019 [35]	80% clay + 20 % sand	high density polyethylene powder	4,8,12	-2 to -9	-3 to -10	--	+13 to +100	--	-21 to -47	+26 to +81	-8 to -12
Al-Taie <i>et al.</i> 2019 [36]	Sandy	Depolymerize waste polyethylene terephthalate	0.5, 1, 1.5, 2	-1 to +3	-11 to -19	--	--	+6 to +17	--	---	--
Al-Neami <i>et al.</i> 2020 [37]	cohesive clayey soil	polypropylene waste fibers	0.25, 0.5, 0.75	-1 to -2	--	--	+32 to +64	+10 to +100	--	--	--
Kadhumi and Aljumaili, 2020 [38]	subbase soil containing of ceramic waste	Domestic plastic waste strips	0.25, 0.5, 0.75, 1	--	---	+1 to +18	--	---	--	--	--
Hassan <i>et al.</i> 2021 [39]	clayey	polyethylene fibers	1, 2, 3,	-1 to -3	-1 to -17	+22 to +80	+63 to +97	--	--	--	--
		Polypropylene fibers	4	-1 to -2	-4	+5 to +50	+48 to +73	--	--	--	--
Fadhil <i>et al.</i> , 2021 [40]	60 % sand + 40 % clay	plastic water bottles fibers	0.25, 0.5, 0.75, 1	---	---	---	+181 to +270	--	--	--	--
Jaber <i>et al.</i> , 2021 [41]	Subbase	recycled polyethylene terephthalate plastic granule	2.5 ,5, 7.5, 10, 12.5 (by vl.)	-1 to -10	-3 to -19	+6 to +36	--	--	--	--	--

3. Conclusions

Consuming the waste plastic materials are environmental ecofriendly resources utilized as a soil stabilizer to diminish the harmful impacts of these waste materials. A review of these waste plastic materials that conducted by Iraqi researchers was displayed and discussed in this article. It was revealed that:

1. Outcomes of numerous local researchers offer an encouraging implication to the opportunity for application the recycled waste plastic for stabilizing or reinforcing of different soil. This employment disposes the waste plastic and reduce using of virgin materials.
2. The insertion of the waste plastic in the soil considerably improve the desired properties of treated soil. The addition of the waste plastic in treated soil ranged from (0.5 - 4.0) wt. % of dry soil. Also, the shape and measurement of added plastic marginally effect on improvement of soil.
3. In general, the compaction properties for treated soil decreased as fraction of waste plastic in soil increased. The reduction in maximum dry density and optimum moisture content for treated soil extended up to 15% and 20 % compared with relative untreated soil.

4. California bearing ratio for the treated soil increased as the percentage of the plastic in the soil increased as well. The rising percentage in the value of California bearing ratio touched about 80% in comparison to the untreated soil.
5. The addition of the waste plastic to soil greatly effect on Atterberg limits. The addition of plastic decrease the plasticity index and liquid limit, however the plastic limit of soil increased. The effect on the Atterberg limits stretched up to 70 %, 81%, and 21% for plasticity index, plastic limit, and liquid limit respectively as compared with natural soil.
6. Unconfined compressive strength and shear strength of the waste plastic treated soil significantly improved when waste plastic added to the soil. The improvement in unconfined compressive strength and shear strength up to 270% and 240%, respectively.

4. Future Works

Upon completion of the present review, the subsequent suggestions are commended for further local investigation on the utilization of waste plastic on stabilization of different locally soils:

1. A comprehensive research is recommended to increases the understanding of the affecting factors on the performance of different treated soil (type of plastic, shape and dimension, higher dosage of plastic than 4% by weight, size or fineness of plastic, and etc.).
2. Study on reinforcing and stabilization of the soils by hybrid methods like combining two or more conventional methods with addition waste plastic.
3. More investigations are necessary to evaluate the surface preparation or treatment of waste plastic before using in soil for adjusting the hydrophobic property of most plastics.

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