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RESEARCH ARTICLE

Impact of Textiled-Poly Bags as Economic and Environmentally Friendly Recycled Fibers on Mechanical Features of Soil

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ABSTRACT

Newly, the utilization of polypropene for packaging consumer products was populated significantly, which might make ecological problems. Hence, it is substantial to detect environmentally friendly techniques to recycle these waste substances without causing any environmental risks. One such technique could be the utilize poly wastes as stabilizer agents for soils. In the current investigation, textiled-poly bags (TPB) have been recycled and fabricated to be economy and environmentally-friendly fibers. The impact of utilizing different proportions and lengths of these fibers on the mechanical features of clayey soil has been evaluated. The investigation depended on four different fiber-proportions (1, 2, 3, and 4%) of soil weight in two different lengths (1 and 2) cm. Geotechnical experimental test consequences demonstrated that the recycled fiber pieces minimize the optimum dry density and the corresponding optimum water content of the treated soil samples. In addition, there was a notable increment in the uniaxial compression test results of the treated soil samples. Moreover, the consequences of California Bearing Ratio tests showed that the utilization of recycled TPB fibers in clayey soil samples enhances the resistance and deformation performance of the soils specially when utilizing 4% of recycled TPB fibers for both lengths (1 and 2) cm. This recycled fiber improves the strength features and dynamic behaviors of clayey soils. Therefore, the recycled TPB fibers could be successfully utilized as reinforcement materials for the modification of clayey soils.

Keywords: Environmentally friendly techniques, Textiled-poly bags, recycled fibers, geotechnical experimental tests

INTRODUCTION

The elimination of waste substances has become prevalent trouble in most of the world's countries. Accumulating this waste in huge amounts causes ecological and monetary troubles.[1] In Iraq, the reports revealed that polypropene waste is the second largest solid waste after food waste.[2,3] Because most plastic waste is non-biodegradable and can remain for several years, several states have planned to reduce or prevent the impact of such waste by recycling or reutilizing it in efficiently techniques in several fields.[4-7] Several civil engineers have performed several investigations to discover successful techniques to minimize the contamination of these substances inclusive of reutilizing and recycling these substances in construction and geotechnical implementations as solutions to preserving the environment from the contamination of polypropene waste substances.[8-16]

LITERATURE REVIEW

The utilization of polypropene waste substances as stabilizer agents for soils is one of successful techniques. Many studies reported that conventional soil stabilizers such as cement and several pozzolanic substances are vastly utilized for enhancing the geotechnical features of weak bearing soils Sherwood,[17] Yadav and Tiwari,[18] and Yadav *et al*.[19] The efficiency of these stabilizers in enhancing soil's features has been proved by several geotechnical engineers Bell,[20] Little,[21] Rout *et al*.,[22] Rasul *et al*.,[23] Rasul *et al*.,[24] Rasul *et al*.,[25] Yadav and Tiwari.[26] Nevertheless, the utilization of these stabilizers in high proportions makes them cost-ineffective, as a result, authors such as Obo and Ytom) attempted to discover alternate cost-effective stabilizer agents such as polypropene, tires rubber chips, and rice hull.[27] Shelema (2020) reported that the utilization of polypropene waste strips as stabilizer substances could enhance the foundation layers of pavements.[28] Consequently, this technique could solve the trouble of waste's cumulative by minimizing its

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amounts and recycling it for improving the characteristics of soils. One technique of utilizing polypropene for soil stabilization was to utilize the polypropene in the shape of separated fibers since when polypropene substances have been merged with soil's particles, they conducted identical behavior of fiber-reinforced soils Temel and Salbas.[29] Many geotechnical investigations have been implemented by Stacy *et al*.[30] and (Temel and Salbas[29] to evaluate the efficiency polypropene waste substances in the shape of separated fibers on soil's features. They reported that utilizing polypropene waste substances for soil stabilization could enhance the features of weak bearing soil like an enhancement in uniaxial compressive resistance, California Bearing Ratio, and reduction in soil's plasticity. Singh and Hussain (2020) utilized different percentages of waste coir fiber with polypropylene fiber for soil stabilization, they discovered that 75% of the fiber content could be the best ratio to improve the features of the soil.[31] Twinkle *et al*. (2011)[32] have investigated the impact of polypropylene fiber, lime admixture, and period of curing on the geotechnical features of clayey soil. They noted that the increase in fiber content caused an increment in resistance features and shrinkage potential and caused a decrement in the swelling potential. Furthermore, the period of curing significantly improved the uniaxial compressive resistance and shear resistance parameters of the treated soil. Jadho and Nagarnik (2008)[33] have investigated the impact of polypropylene fibers in the geotechnical features of soil treated with fly-ash by utilizing various fiber lengths (6, 12, and 24 mm) with the range of (0–1.5% by dry wt. of the soil). They noted that the optimum improvement in the resistance features could be achieved at a fiber length of (12 mm), and the optimum proportion of fiber content was (1%). According to the literature, the tensile resistance values of strengthened stabilized soil with polypropylene fibers have improved to a great extent. The highest resistance values have been collected with approximately (0.5–1.0%) fiber content for the (12 mm) length. The value of shrinkage limits improved with increasing fiber content and length of the fiber, whereas volume changes and cracks have been minimized.[34-39] However, there are no investigations implemented in stabilizing clayey soil with fabricated textiled-poly bags (TPB) to evaluate the geotechnical features of such stabilized soil.

This work is a sustainable and environmentally friendly experimental study focuses on the impact of utilizing different proportions (0, 1, 2, 3, and 4%) and different lengths (1 and 2 cm) of fabricated TPB on the mechanical features of clayey soil.

MATERIALS AND METHODS

Soil

Soil samples which utilized in the current investigation have been collected from Raparin area, in the Sulaymaniyah governorate of the Kurdistan region of Iraq, from a depth one meter below the ground level. The collected samples have been immediately preserved in anti-evaporation plastic bags and then transported to the engineering laboratory. The essential characteristics of the collected soils and the corresponding standards which were depended in evaluations are demonstrated in Table 1. The collected soils have been categorized as clayey soils based on USCS (ASTM-D2487-17)[40] and the volume distribution curve was assessed and plotted according to ASTM-D422-63[41] [Figure 1]. The compaction tests curve has been evaluated and plotted according to ASTM-D698-12R2021[42] [Figure 2] which gave an optimum water content (OWC) value of about 23% with an optimum dry density (ODD) of about 1545 kg per cubic meter.

Recycled Fiber

The fiber has been obtained from recycling waste TPB. The TPB waste has been cut into strips of two different lengths (1 cm and 2 cm) with widths ranged between 2.5 and 3 mm. These fabricated TPB fibers have a tensile resistance about 125 MPa, with 3000 MPa Young's modulus, and 73% ultimate linear strain.

Table 1: Essential characteristics of the collected soil

Characteristics	Values	Standards
G_s	2.7	ASTM-D854-14[43]
ODD (kg/m^3)	1545	ASTM-D698-12R2021[42]
OWC (%)	23	ASTM-D698-12R2021[42]
Atterberg limits		
LL (%)	55.8	ASTM-D4318-17E01[44]
PL (%)	29.1	ASTM-D4318-17E01[44]
PI (%)	26.7	ASTM-D4318-17E01[44]

ODD: Optimum dry density, OWC: Optimum water content

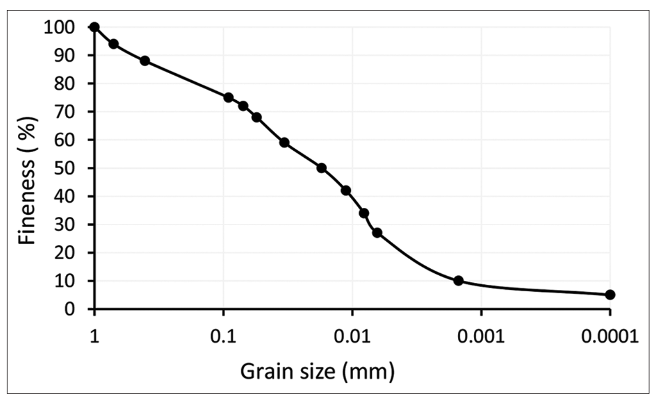

Figure 1: Volume distribution curve of collected soil

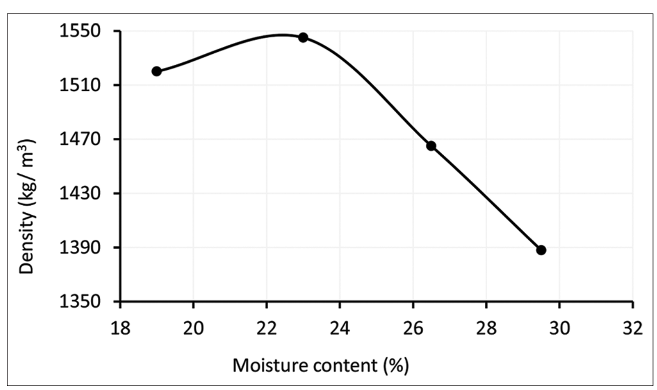

Figure 2: Compaction curve of collected soil

Test Methods

In current investigation, to evaluate the resistance and geotechnical features of both natural untreated clayey soil and treated soil, several experimental tests have been performed inclusive the evaluation of index characteristics of untreated soil, proctor compaction, uniaxial compressive resistance, and California Bearing Ratio for both untreated and treated soil. These experimental tests have been performed depending on ASTM standards. First, the recycled TPB fibers have been gradually added to the air-dried soil and mixed by hand. Significant care has been taken to get best homogeneous between soil particles and fiber strips. After that, the desired water has been added to get soil samples ready to test. Depending on ASTM-D698-12R2021,[42] compaction tests have been implemented for evaluating the impact of TPB fibers on OWC and ODD of treated soil, which have been adopted later for uniaxial compressive resistance test and California Bearing Ratio test. The ASTM-D2166-06[45] standard has been depended to implemented the uniaxial compressive resistance test to evaluate the impact of TPB fibers of uniaxial compressive resistance of treated soils. Furthermore, ASTM-D1883-21[46] standard has been depended to evaluate load per cylindrical test sample (150 mm diameter, 175 mm height) demand to penetrate a soil mass with uniform rate of 1 mm/min. This test was depended to evaluate California Bearing Ratio by dividing the test load by standard load.

RESULTS AND DISCUSSION

Impact of TPB Fibers on the Parameters of Compaction Test

The results of proctor compaction tests have demonstrated that the utilizing of TPB fibers at different percentages (0, 1,2, 3 and 4%) and different lengths (1 cm and 2 cm) gives dissimilar behavior in terms of OMC and ODD [Figures 3 and 4].

When utilizing TPB fiber at 1-cm length, ODD minimized by 2.31% and 1.61% for fiber content 1% and 2%, consecutively, and increased by 1.16% and 1.55% when fiber content was increased to 3% and 4%, consecutively. Moreover, when utilizing TPB fiber at a 2-cm length, ODD minimized by 0.97%, 0.58%, 0.71%, and 1.23% for fiber content 1%, 2%, 3%, and 4%, consecutively. The relation between ODD and length of TPB fiber is demonstrated in Figure 5, which could summarize the impact of fiber length and its content on the values of ODD.

When utilizing TPB fiber at 1-cm length, OWC increased with increasing fiber content about 3.18%, 0.45%, and 2.72% for fiber content 2%, 3%, and 4%, consecutively, however at 1% fiber content, the OWC minimized by 5.45%. Moreover, when utilizing TPB fiber at a 2-cm length, OMC minimized by 1.36%, 2.72%, 3.63%, and 1.36% for fiber content 1%, 2%, 3%, and 4%, consecutively. The relation between OWC and length of TPB fiber is demonstrated in Figure 6, which could summarize the impact of fiber length and its content on the values of OMC.

Impact of TPB Fibers on the Behavior of Uniaxial Compressive Resistance

The results of uniaxial compressive resistance tests [Tables 2 and 3] have demonstrated that the utilizing of TPB fibers at different percentages (0, 1, 2, 3, and 4%) and different lengths (1 cm and 2 cm) gives almost similar behavior in terms of improving the resistance.

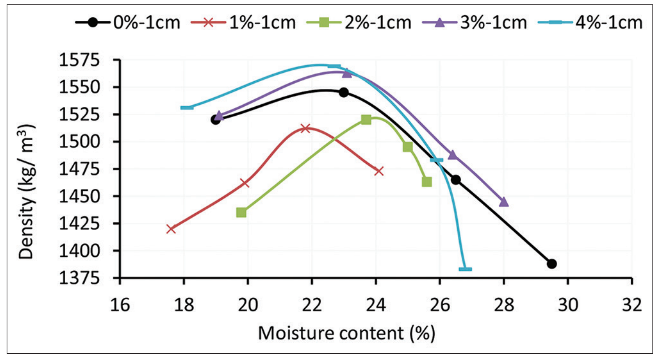

Figure 3: Compaction curve for TPB fiber at 1-cm length

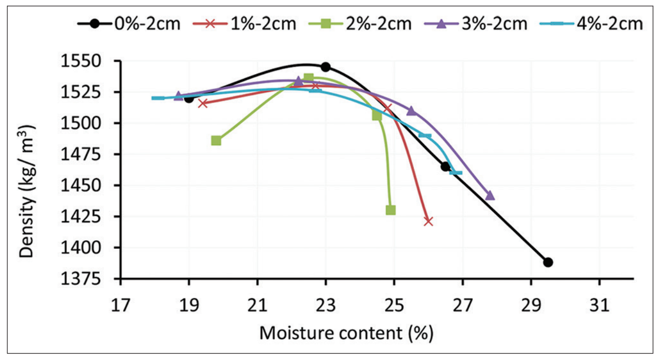

Figure 4: Compaction curve for TPB fiber at 2-cm length

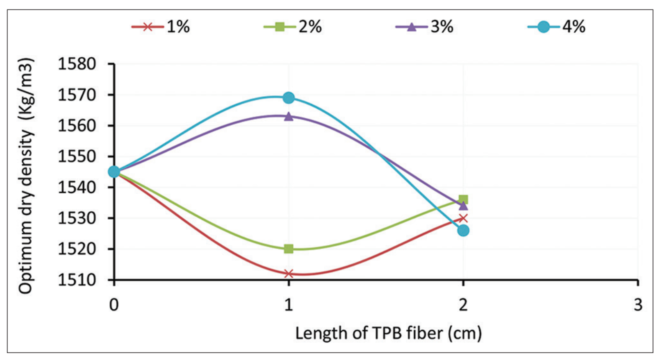

Figure 5: The relation between ODD and length of TPB fiber

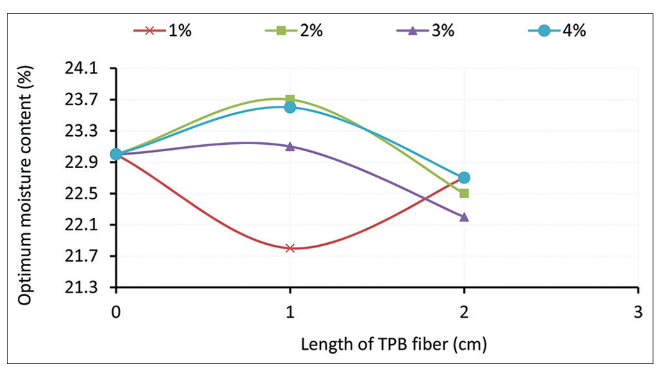

Figure 6: The relation between OMC and length of TPB fiber

When utilizing TPB fiber at 1-cm length, uniaxial compressive resistance increased by 57.04%, 50.33%, 48.99%, and 48.32% for fiber content 1%, 2%, 3%, and 4%, consecutively. Moreover, when utilizing TPB fiber at 2-cm length, the increment in uniaxial compressive resistance reached about 75.16%, 61.74%, 63.75%, and 65.77%, for fiber content 1%, 2%, 3%, and 4%, consecutively.

The comparative between TPB fiber at 1-cm length and TPB fiber at 2-cm length in terms of the behavior of uniaxial compressive resistance is demonstrated in Figure 7. It could be seen that the utilizing of TPB fiber at 2-cm length gives the highest improvement.

Impact of TPB Fibers on the Behavior of California Bearing Ratio

The results of California Bearing Ratio tests [Tables 4 and 5] have demonstrated that the utilizing of TPB fibers at different percentages (0, 1, 2, 3, and 4%) and different lengths (1 cm and 2 cm) gives significant improvement in the values of California Bearing Ratio.

When utilizing TPB fiber at 1-cm length, California Bearing Ratio increased by 10%, 36.66%, 50%, and 63.33% for fiber content 1%, 2%, 3%, and 4%, consecutively. Moreover, when

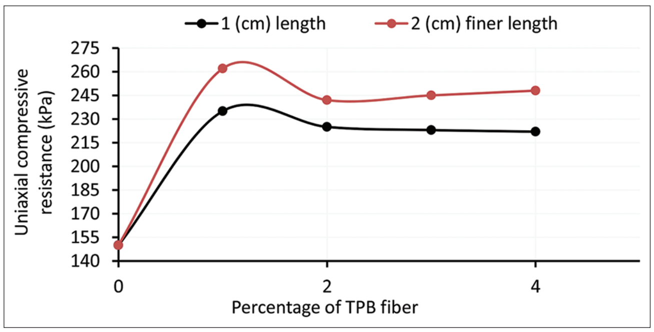

Figure 7: Comparative in uniaxial compressive resistance results

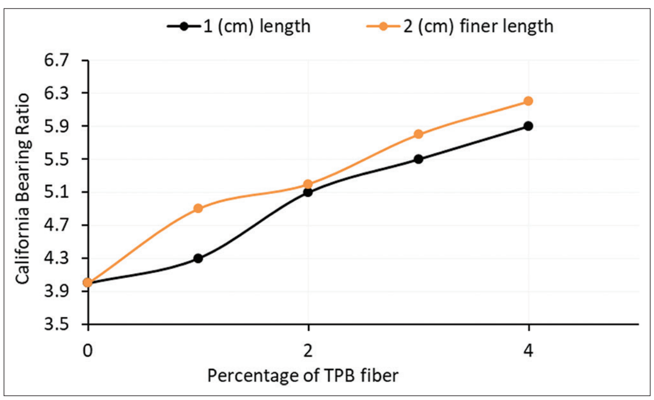

Figure 8: Comparative in California bearing ratio results

Table 2: Impact of TPB fibers at 1 (cm) length on the behavior of uniaxial compressive resistance

Percentage of TPB fiber	Uniaxial compressive resistance (kPa)	Increment (%)
0	150	/
1	235	57.04
2	225	50.33
3	223	48.99
4	222	48.32

Table 3: Impact of TPB fibers at 2 (cm) length on the behavior of uniaxial compressive resistance

Percentage of TPB fiber	Uniaxial compressive resistance (kPa)	Increment (%)
0	150	/
1	262	75.16
2	242	61.74
3	245	63.75
4	248	65.77

Table 4: Impact of TPB fibers at 1 (cm) length on the behavior of California bearing ratio

Percentage of TPB fiber	California Bearing Ratio	Increment (%)
0	4	/
1	4.3	10
2	5.1	36.66
3	5.5	50
4	5.9	63.33

Table 5: Impact of TPB fibers at 2 (cm) length on the behavior of California bearing ratio

Percentage of TPB fiber	California bearing ratio	Increment %
0	4	/
1	4.9	30
2	5.2	40
3	5.8	60
4	6.2	73.33

Table 6: Conclusion of the mechanical behavior

Percentage of TPB fiber (%)	Length of TPB fiber (cm)	Mechanical behavior	
		Uniaxial compressive resistance (kPa)	California bearing ratio
0	1	150	4
1		235	4.3
2		225	5.1
3		223	5.5
4		222	5.9
1	2	262	4.9
2		242	5.2
3		245	5.8
4		248	6.2

utilizing TPB fiber at 2-cm length, the increment in California Bearing Ratio reached about 30%, 40%, 60%, and 73.33%, for fiber content 1%, 2%, 3%, and 4%, consecutively.

The comparative between TPB fiber at 1-cm length and TPB fiber at 2-cm length in terms of the behavior of California Bearing Ratio is demonstrated in Figure 8. It could be seen that the utilizing of TPB fiber at 2-cm length gives the highest improvement.

CONCLUSION

The investigation was implemented to fabricate environmentally friendly fiber by recycled TPB and evaluate its impact on several geotechnical features of clayey soil. The behavior of utilizing this fiber in several content and several lengths has been evaluated and the results could be concluded in the following points:

- The utilizing of 3% and 4% of TPB fiber at 1-cm length helps to improve the parameters of compaction test
- The utilization of 2-cm TPB fiber instead of 1-cm TPB fiber reduces the parameters of compaction test
- TPB fiber improves the uniaxial compressive resistance; this has been noted for all fiber content (1%, 2%, 3%, and 4%)
- TPB fiber of 2-cm length gives highest improvement in terms of uniaxial compressive resistance; this has been noted when compared it with TPB fiber of 1-cm length
- California Bearing Ratio values improve when utilizing TPB fiber of 1- and 2-cm lengths and this has been noted for all fiber content (1%, 2%, 3%, and 4%)
- TPB fiber of 2-cm length gives highest improvement in terms of California Bearing Ratio; this has been noted when compared it with TPB fiber of 1-cm length.

The overall mechanical behavior which gated from the current work could be concluded in Table 6 below.

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