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The Use of Shredded Plastic Water Bottles in Soil Stabilization

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Abstract: Please Soil stabilization is a mechanical or chemical procedure to improve the physical properties of weak soil. In this research, a mechanical process of using shredded plastic water bottles has been investigated in soil stabilization. To achieve the objective of this research, two types of clayey soils have been selected based on their plastic indices. The initial mechanical properties of the two soils have been determined using ASTM standard procedures. A plastic water battles were shredded into small pieces with dimension 1.0 cm in length and 2.0 – 3.0 mm in width. The shredded plastic was added to the clayey soil at 6 different percentages by dry weight of the soils 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, and 3.0% with 0.5 increment. Standard compaction and unconfined compression test were conducted on soil plastic mixtures at the 6 different percentages. It was found that the addition of shredded plastic to the clayey soils reduced both the maximum dry density and optimum moisture content for the two types of soils. However, a significant increase in unconfined compression test was noticed due to the addition of shredded plastic waste. The highest increase was noticed at 1.5% by dry weight of the soil. Additionally, the failure strain was decreased due to the addition of the plastic waste.

Keywords: Soil stabilization, Plastic waste, Unconfined compressive strength, Optimum moisture content.

Introduction

Disposal of municipal and industrial waste materials has become a major environmental and financial problems in the entire world due to the huge amount of generated and accumulated waste such as plastic waste, ceramic waste, waste rubber tires, etc. resulted from the rapid urbanization and industrialization. Plastic waste materials are considered the most common waste materials. Such material is generated in substantial quantities and considered the humans' daily life most usable material category. A recent study was conducted in 2019 has evaluated the impacts of plastic pollution on the sustainability of seafood value chain reported that the average waste generation was estimated at 15.4 billion fragments per day (Awuchi et. al. 2019). Another study reported that 1.5 billion units of tires are generated throughout the globe approximately (Thomas et. al., 2016) Another study reported that 8-12% of the annual total generated municipal and industrial wastes are plastics which almost represent 190 million tons (Wong et. al., 2015). In 2008 a study was conducted in Australia which reported that plastic wastes comprise 16% of the municipal waste stream which stands for 2.24 million tones (Bajracharya et. al., 2016). The increase of production of wastes and plastics in particular was influenced by many elements such as population growth, the wide variety of applications, and the low production cost (Meran et. al., 2008). Plastics wastes contain several types, however, the main contributor to the large volume of plastic wastes are polyethylene end products (Wong et. al., 2015). Polyethylene is used to comprise many products such as polyethylene terephthalate (PET) which include plastic bottles, high-density polyethylene (HDPE) which include the leaning agents and laundry detergents, polyvinyl chloride (PVC) which include trays for sweets and plastic packing, low-density polyethylene (LDPE) which include the shopping bags, etc. In Kurdistan/Iraq the main components of waste materials are considered to be polyethylene products. In 2012 a

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study was performed to study the effect of using waste polyethylene production on mechanical properties of concrete reported that more than 5000 tons of polyethylene is produced as waste materials every day in Duhok city (Hanna et. al., 2012). Even while plastics have several benefits, they are posing negative effects on the health and environment since most of these products are not biodegradable. This is why efficient recycling and reusing of these materials is considered one of the most important elements addressed by most of the countries nowadays.

To maintain and preserve the environment from the negative impacts of plastic waste materials, several researchers have conducted studies to obtain efficient methods that can minimize the pollution of these materials such as recycling and reusing these products in civil engineering applications. A study was performed in 2018 which found out that using plastic wastes as an alternative to stabilize the soil used for road construction is considered an effective method (Tatone, et al., 2018). Cement and lime are considered the two traditional materials used to enhance the geotechnical properties of weak soils and they're widely used in soil stabilization (Sherwood, 1993; Yadav et. al., 2016; Yadav et. al., 2018). Many studies have been performed and proved the effectiveness of using these materials as soil stabilizers (Bell, 1996; Rout et. al., 2012; Rasul et. al., 2015). Still, numerous researchers are trying to discover alternatives to cement and lime such as plastic, tire chips, etc. since high usage of cement and lime can make them unsustainable in terms of cost (Obo et. al. 2014).

In 2011, a study was performed to study the effect of fibers on some engineering properties of cement and lime stabilized soils and reported that using plastic wastes as a soil stabilizing material can enhance the foundation layers of pavement (Khattab et. al., 2011) which can enhance the properties of soils and decrease the amount of waste. The usage of plastics in the shape of discrete fibers in considered one method of integrating this material in soil stabilization since it tends to behave similar to fiber-concrete soils when merged with soil (Yetimoglu et. al., 2003). To verify the effectiveness of improving soils properties by using plastic waste materials as discreet fibers, many studies have been conducted. (Ziegler et. al., 1998; Babu et. al., 2011; Mondal, 2012; Ahmadinia et. al., 2012; Peddaiah et. al., 2018; Hassan et. al., 2021) All these studies reported that the use of plastic wastes in soil stabilization will enhance the properties of the soils such as UCS, CBR. As a result, the aim of this research is to evaluate the adaptation of a mechanical process using shredded plastic water bottles on soil stabilization.

Experimental Program

Selection and Classification of Tested Soils

The chosen soils for this research were selected to be clay. Two types of clay soils were selected which are high-plasticity clay soil (CH) and low-plasticity clay soil (CL). The physical properties of the two soils were determined by conducting several laboratory tests such as particle size distribution, Atterberg's limit test, Proctor compaction test, and specific gravity test. All the tests which were performed according to the ASTM standards.

Plastic Waste Material and Preparation of Samples

The plastic waste materials (PWM) were introduced in this research by gathering some polyethylene terephthalate (plastic water bottles) since they represent the most common used type of the plastic wastes in the daily life. To use the plastic water bottles wastes were used to play the role of fiber stabilizers. To achieve this object, PWM were cut and shredded into a 1cm size in length and 1-2mm size in width. Figure 1 represent a sample of the used PWM. The prepared PWM were distributed into six groups which each reflect a percentage of the dry weight of the soil. The fiber pieces were applied at 0.5%, 1%, 1.5%, 2%, 2.5%, and 3% of dry weight of the clayey soils. Afterwards, each soil was divided into seven different portions. Each portion was mixed with one of the PWM percentages based on the dry weight and the last sample portion represented the 0% fiber content to present the native soil outcomes. Subsequently, proctor compaction test was performed in accordance with the ASTM D698 using the different prepared fiber samples to obtain the maximum dry density and optimum water content and to understand the influence of PWM on these two parameters. Consequently, remolded samples were prepared at 95% relative compaction and using the optimum water content obtained in the unconfined compression mold. Leave one blank line after each heading and two blank lines before each heading. (Exception: leave one line between consecutive headings.) Please margin all headings to the left. Leave one blank line after each heading and two blank lines before each heading. (Exception: leave one line between consecutive headings.) Please margin all headings to the left.

Figure 1: PWM sample

Laboratory Tests

To evaluate the effect of the PWM on the clay soils, different types of tests were required to be conducted. As mentioned earlier, to classify the clay soils and obtain the raw physical properties of the tested soils particle size distribution, Atterberg's limit, Proctor compaction, and specific gravity tests were performed. After preparing the different needed samples, the strength of the prepared samples and the effect of the PWM on the unconfined compression strength was acquired by conducting Unconfined Compressive Strength Test. The test was conducted based on ASTM D2166 procedures. The test was performed on the remolded samples. All the data were collected and analyzed. All the tests were performed at American University of Sharjah laboratory.

Results and Discussion

The Effect of the PWM on Compaction Parameters

Figure 2 and Figure 3 depicts the effect of PWM on the compaction parameters mainly maximum dry density and the optimum water content. It is clear from the figures that as the percentage of the PWM is increasing, the maximum dry density and the optimum water content of the different mixtures tend to decrease as the curves tend to get lower and shift to the left. This outcome can be justified based on the fact that PWM has less density than the clay soil and it will replace the soil in the mold which will lead to lower the maximum dry unit weight. Moreover, the PWM doesn't not absorb water which will lead to reduce the optimum water content as illustrated in Figure 4 and Figure 5.

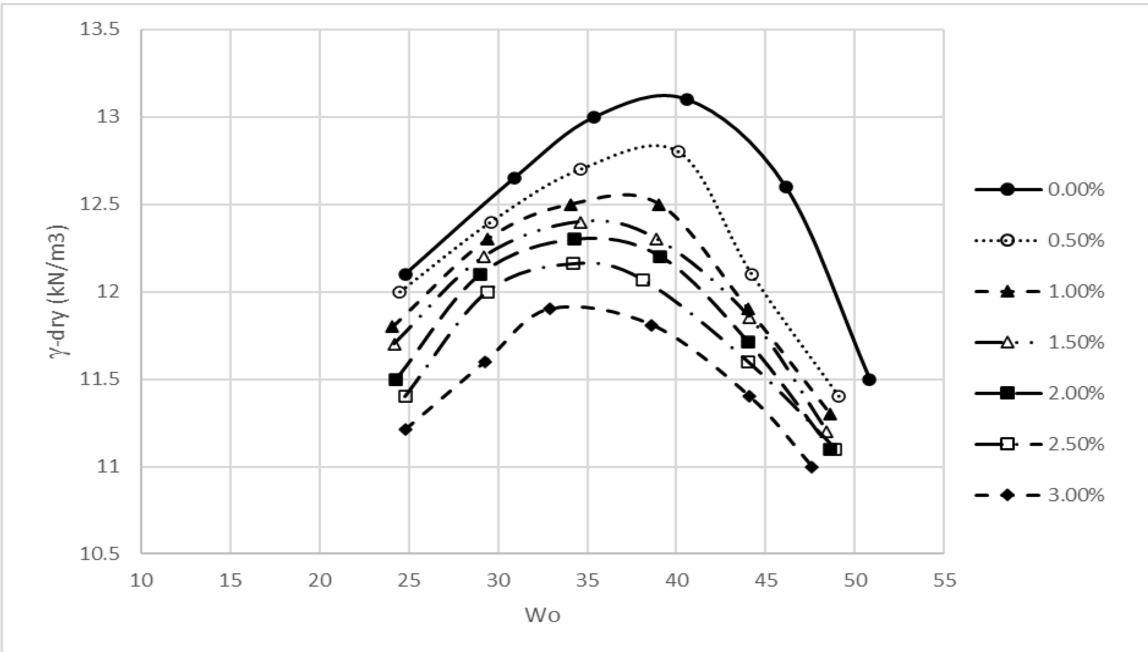

Figure 2: Compaction curve for CH soil.

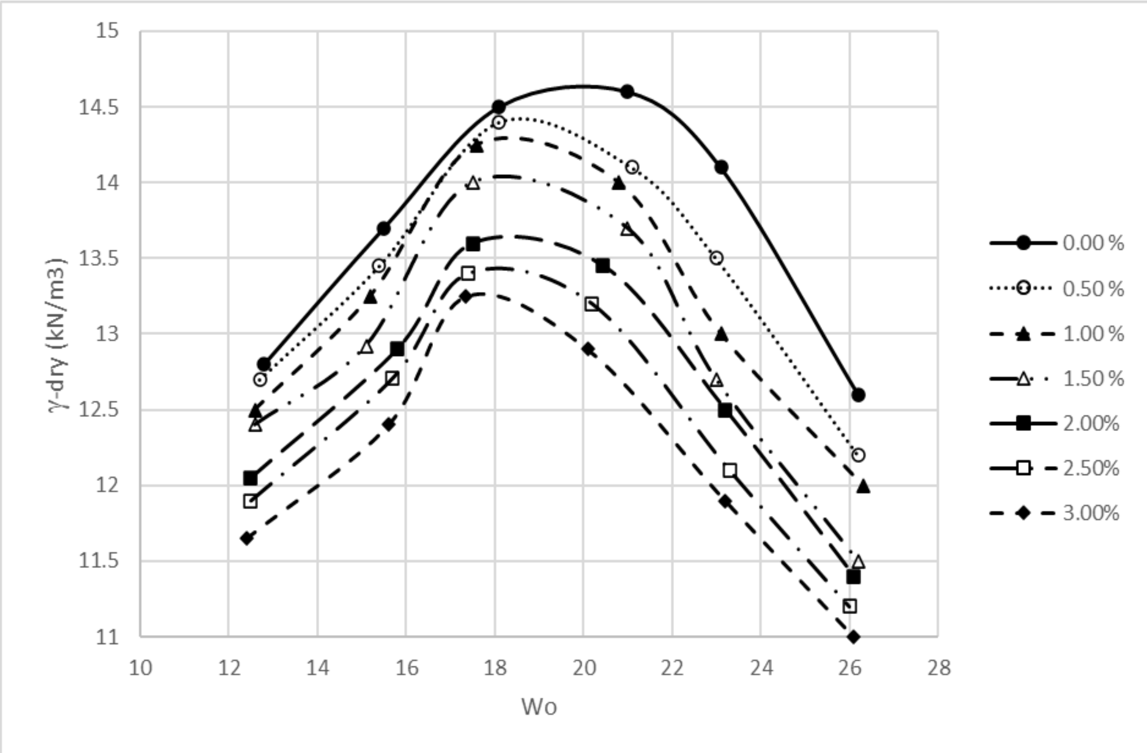

Figure 3: Compaction curve for CL soil.

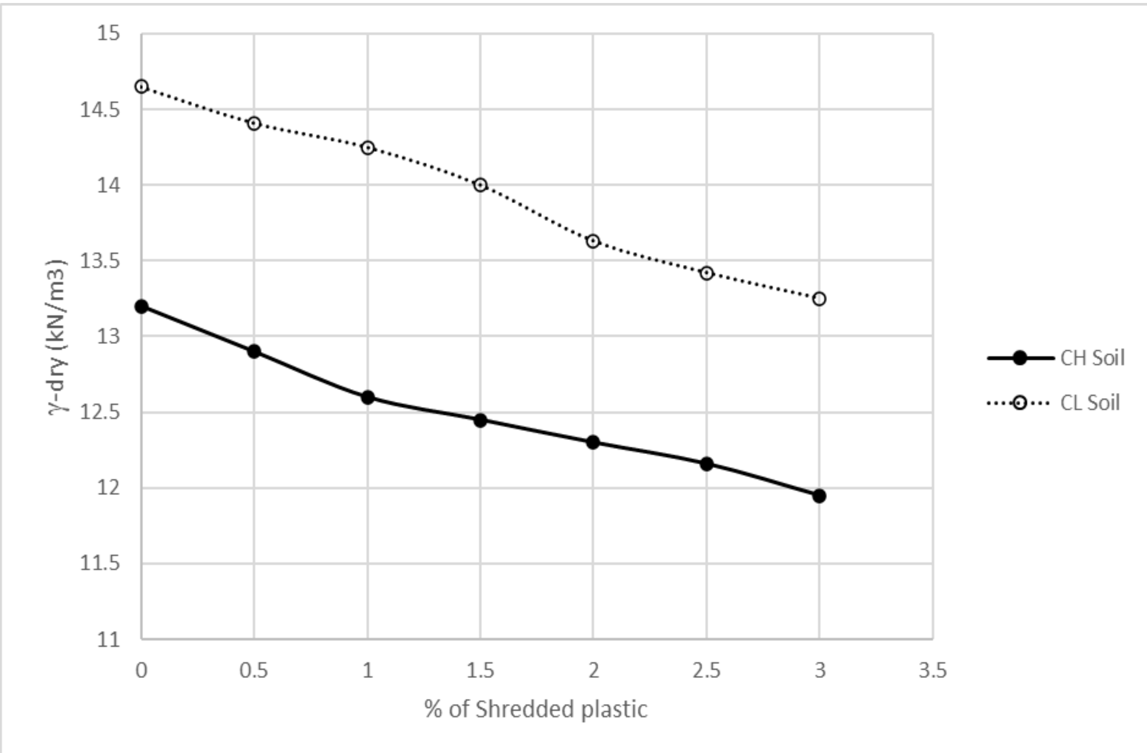

Figure 4: Maximum dry density with respect to the percentage of shredded plastic waste added.

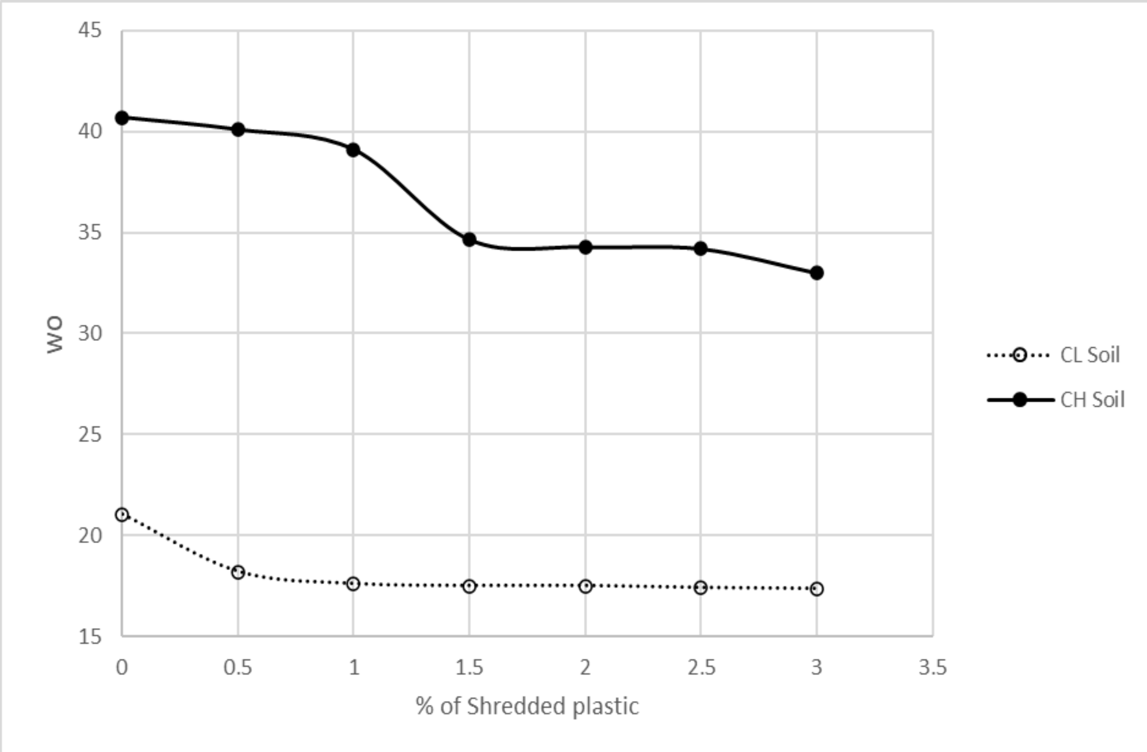

Figure 5: Optimum water content with respect to the percentage of shredded plastic waste added.

The Effect on the PWM on the Unconfined Compression Strength

Figure 6 represents the influence of PWM on the unconfined compression strength. It's clear that the addition of PWM led to a noticeable improvement in the unconfined compression strength of both soils up to a specific percentage which is 1.5%. This could be attributed to the fact that the added PWM formed a deep contact with the soil while keeping in mind that some of the fiber will intersect to the failure plane which will result in increasing the unconfined compression strength. The results reported that this trend is applicable up to 1.5%. Afterwards, increasing the percentage of PWM in the soil mixture will cause a reduction in the strength of the soil which is logical as the presence of additional PWM in the soil will reduce the cohesion since clay particles are being replaced with plastic even while considering the contact with the remaining clay soil.

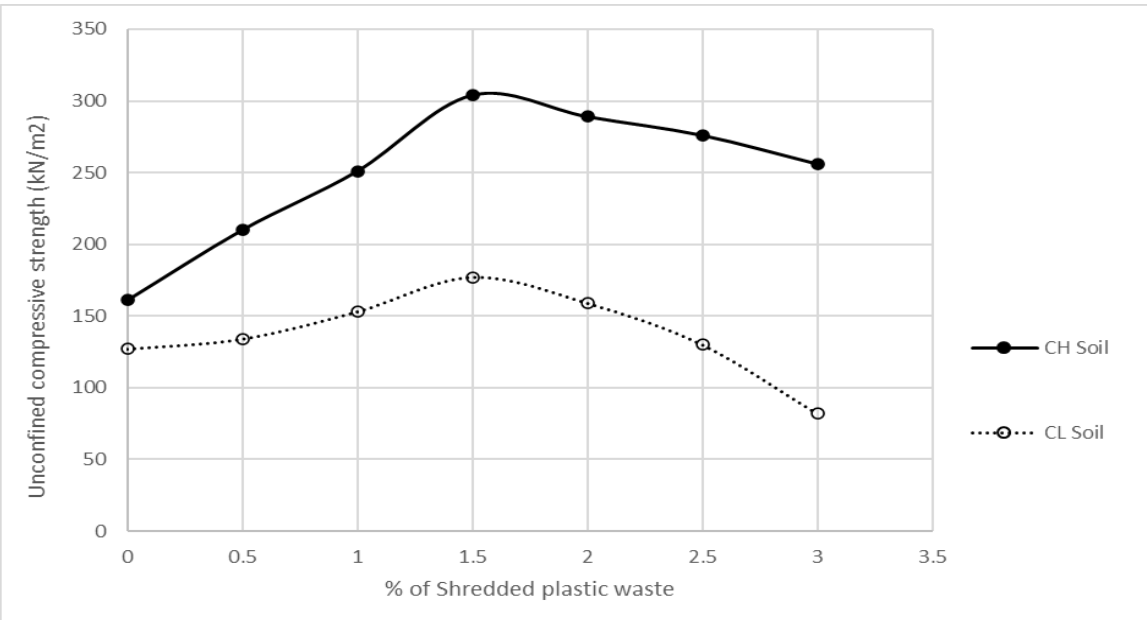

Figure 6: Unconfined compression test.

The Effect on PWM on Failure Strain

Figure 7 illustrates the impact of PWM on the failure strain of the soil. It's clear that the increase in the percentage of the PWM in the soils lead to decrease the percentage of the anticipated failure strain. This is primarily due to the fact that the nature of the added PWM is considered to be non-cohesive which will directly result in decreasing the failure strain and hence, the failure of the samples will occur at lower strain values.

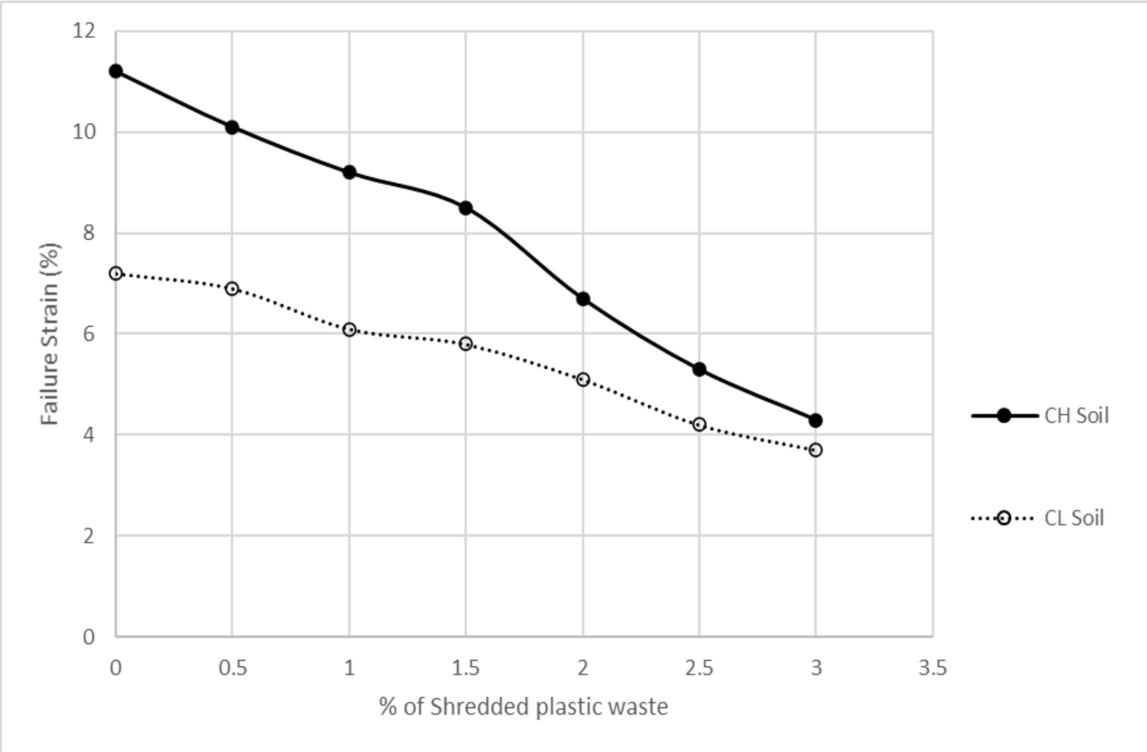

Figure 7: Percentage of failure strain with respect to the percentage of shredded plastic waste.

The Effect on the PWM on the Modulus of Elasticity

Figure 8 depicts the effect on the modulus of elasticity resulted from the addition of different percentages of PWM to the selected soils. It's obvious that increasing the percentage of PWM led to increase the value of the elastic modulus for both soils up to a specific percentage which is 1.5%. The reason behind this trend lies in the fact that the added PWM developed a deep contact causing the improvement in the modulus of elasticity and hence, an improvement in the strength of the mixture. Yet, the results showed that this trend is valid up to 1.5% of the added plastic material. After that, any additional increase in the PWM to the soil will tend reduce the strength of the soil as the presence of more PWM in the soil will decrease the cohesion of the soil since clay particles are being replaced with plastics which will reduce the overall cohesion of the clay soils.

Conclusion

The major conclusion of this research obtained from the several conducted tests are presented in this section.As the percentage of the added shredded plastic waste is increasing, the maximum dry density and the optimum water content of the different samples tend to decrease.The addition of shredded plastic waste up to 1.5% led to a noticeable improvement in the unconfined compression strength of both soils.Increasing the percentage of the shredded plastic waste in the soils led to decrease the percentage of the anticipated failure strain.Increasing the percentage of shredded plastic waste led to increase the value of the elastic modulus for both soils up to a specific percentage, which is 1.5%. Higher percentages more than 1.5% of the shredded plastic waste in the soil increase will decrease both the unconfined compressive strength and the modulus of elasticity.

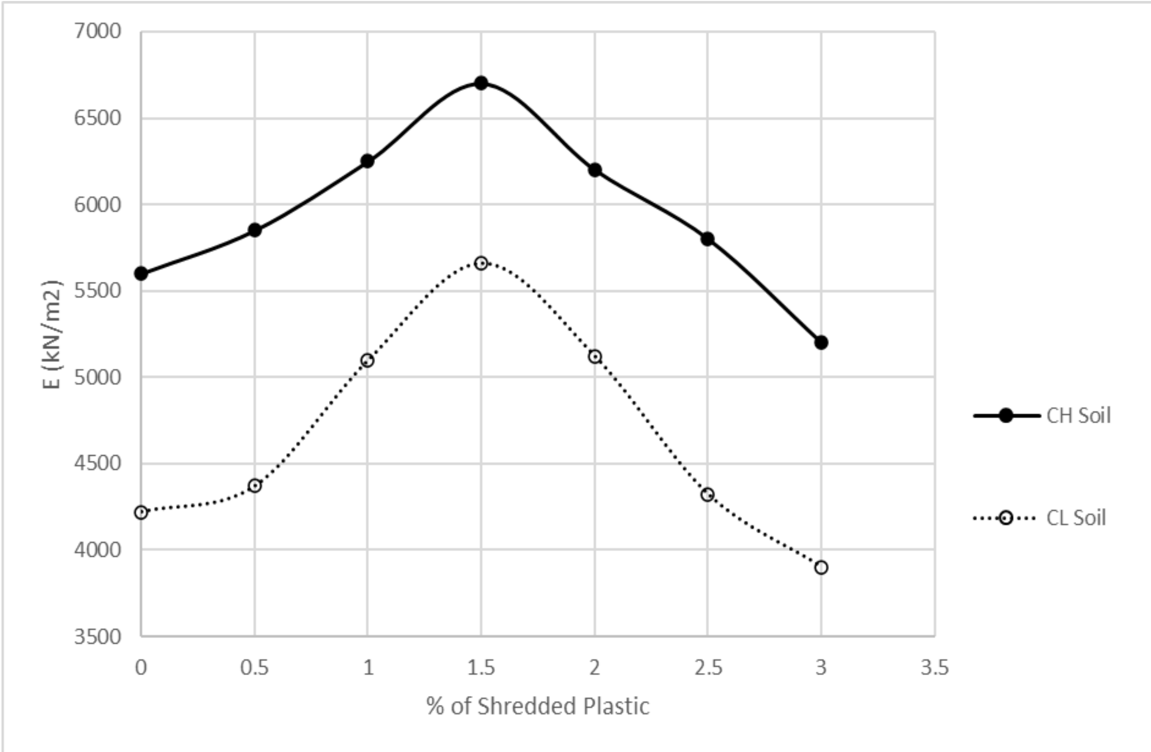

Figure 8: Modulus of elasticity with respect to the percentage of shredded plastic waste.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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