Journal for Educators, Teachers and Trainers
The PROFESIOLab electronic, peer-reviewed, open-access Magazine

**ISSN 1989-9572**

**DOI: 10.47750/jett.2022.13.06.090**

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**Journal for Educators, Teachers and Trainers, Vol. 13 (6)**

https://jett.labosfor.com/

Date of reception: 15 Oct 2022

Date of revision: 04 Nov 2022

Date of acceptance: 05 Dec 2022

Mr. A. Sai Vardhan1 Mrs. K. Aparna1, Mr.G.Ramudu1, Mr. B Srikanth1 (2022). Sustainable Soil Stabilization: Enhancing Black Cotton Soil Properties with Recycled College Waste Plastic Fibers. Journal for Educators, Teachers and Trainers,
Vol.13(6)948-954

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# Sustainable Soil Stabilization: Enhancing Black Cotton Soil Properties with Recycled College Waste Plastic Fibers

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**ABSTRACT**

The stabilization of black cotton soil, a problematic expansive soil, is crucial for improving its strength and durability in infrastructure projects. This study investigates the feasibility of utilizing waste plastic fibers collected from college premises as a sustainable stabilizing material for black cotton soil. By integrating plastic waste into soil stabilization techniques, this research aims to reduce plastic pollution while enhancing soil properties for construction applications.

The study follows the Highway Research Board (HRB) classification to analyze black cotton soil characteristics using the Core Cutter Method for sampling. Various laboratory tests, including Sieve Analysis, Atterberg Limits (Liquid Limit and Plastic Limit), Standard Proctor Test (Optimum Moisture Content and Maximum Dry Density), and California Bearing Ratio (CBR) test, were conducted to assess soil behavior with the addition of plastic fibers.

The experimental results indicate that the liquid limit and plastic limit of the soil decrease with the incorporation of plastic fibers, suggesting an improvement in soil consistency. The Maximum Dry Density (MDD) initially increases up to 0.9% fiber content, beyond which it starts to decline, whereas the Optimum Moisture Content (OMC) reduces with fiber addition. The CBR test results confirm that the strength and load-bearing capacity of black cotton soil improve with the inclusion of plastic fibers, making it a viable alternative for soil stabilization in pavement and foundation construction.

From the findings, 0.9% plastic fiber by weight of soil is determined to be the optimum content for improving the engineering properties of black cotton soil. This research demonstrates that waste plastic fibers can be effectively repurposed as a soil stabilizer, offering both environmental and engineering benefits. Utilizing recycled plastic waste in soil stabilization reduces dependency on conventional stabilizers, minimizes waste accumulation, and promotes eco-friendly construction solutions.

This study emphasizes the potential of plastic waste in geotechnical engineering, contributing to sustainable soil improvement practices. Further research could explore long-term durability, field-scale applications, and alternative waste materials for large-scale implementation in infrastructure projects.

**Keywords:** Grading by Sieve Analysis, Atterbergs Limits, Liquid limit, Casagrande Method, Plastic limit, Standard Proctor Test, California Bearing Ratio (CBR) test, plastic fiber.

## 1. INTRODUCTION

Soil modification is the stabilization process in which improvement in some property of the soil but does not result in a significant increase in soil strength and durability (IRC: SP:89-2010). Soil properties like strength, compressibility, workability, swelling potential and volume change tendencies may be altered by various soil stabilization and modification methods. Stabilization is derived by thermal, mechanical, chemical or electrical means. Thermal and electrical is rarely used and less data is available about these two. Mechanical stabilization or compaction is the densification of soil by the use of mechanical energy. By the densification air is expelled from the soil voids without much change in moisture content. This method is used to stabilize cohesionless soils where compaction energy can cause rearrangement and interlocking of particles. But the techniques are not effective if the soil is subjected to significant moisture fluctuation. The efficiency of compaction may also diminish with an increase of fine content, fraction smaller than 75micron, of the soil. This is because inter particle bonding and rearrangement during compaction. Changing the physio-chemical properties of fine-grained soil by chemical stabilization is a more effective form of durable stabilization then densification. Chemical stabilization of non-cohesive, coarse grained soil with greater than 50% by weight coarser than 75micron is also profitable if a substantial stabilization reaction achieved in the soil (Dallas and Syam, 2009).

## 2. LITERATURE REVIEW

(Mai et al., 2017), through their study laboratory investigation which was carried out on a sub grade clayey soil sample admixed with plastic bottle strips at different percentages of 1% and 2% with dimensions of (10*1) mm and they tested them by various experiments like specific gravity, sieve analysis, proctor compaction test, swell index test, unconfined compressive strength test and CBR test. They found that direct shear of soil containing 1% of fibers increased by 66% but in the case of 2% it increased by 115%, unconfined Compressive Strength of soil containing 1% of fibers increased by 70.8% but in the case of 2% it increased by 175%, the specific gravity dry density and optimum moisture content (OMC) increases as the plastic fibers percentage increases, and the Free swell index also increases with fibers. So that, they found that on adding plastic strips into the soil, there has been a positive impact on properties of soil in favor of road construction, [14].

(Singh and Sonthwal, 2016), they collected clayey soil sample with Inorganic clay of low plasticity (CL) and added waste plastic bottles fibers to clayey soil in different sizes (25*5) mm, (35*10) mm, and (50*15) mm by weight of the dry soil sample with percentages (2%, 4% and 6%) of waste plastic bottles material by weight of the dry soil sample, to improve its engineering properties. They found that, the optimum moisture content (OMC) increased and Maximum Dry Density (MDD) decreased in addition of waste plastic bottles strips. The CBR is found to increase with the increase in the percentage of plastic bottles strips content. Where, 6% plastic fibers by weight of dimensions of (25*5) mm is the specific value, where the CBR got improvement of 27.33 % compared to plain soil. They found that, this can noticeably reduce the total thickness of the pavement and hence the total cost. So that, from this study it is clear that the higher percentage was better and the best dimensions were (25*5) mm. and they highly recommended 6 % with size of (25*5) mm, [15].

(Gowtham and Sumathi, 2017), they added PET fibers to expansive soil (Black cotton soil) (clay of high plasticity) with fiber content of (0.5%, 1.0%, 1.5%, and 2.0%) with size passes through (10mm) sieve is used in this investigation by weight of dry soil and tested them for Atterberg's limit, Compaction Test, Swell Index, CBR, and UCS Test. The result showed fairly significant decrease in the values of Atterberg's limits liquid limit, plastic limit and plasticity Index. Regarding compaction, with the increase of fibers content optimum moisture content goes on decreasing while maximum dry density goes on increasing, hence compact ability of soil increases and making the soil denser and harder. California bearing ratio (CBR) of soil samples increased and also increased as fiber content increased. And in unconfined compressive strength (UCS) compressive strength increased and also increased as fiber content increased. So that, they higher the plastic percentage the higher the improvement in the properties of soil, [16].

(Mohammed et al., 2018), investigated the efficiency of adding of plastic bottle (PET) to clay soil as soil reinforcement. Laboratory compaction and triaxial tests were conducted. Plastic bottles fibers (PET) of length (5-10) mm were used as reinforcement. Soil samples were compacted at maximum dry density with various percentage of waste plastic bottle fibers (0.5, 1.5, 3, 6, 12 and 15) % of weight of soil. They found that the maximum dry density decreased with the increase in the PET content. Also, an increasing of PET bottle waste content decreased the optimum moisture content. In addition, an increases of PET waste significantly reduced the cohesion(c) of soils. The study generally recommended to use this method but not more than 1.5% of PET bottle waste, [17].

(Consoli et. al., 2002), they put waste plastic fibers to uniform fine sand and tested it under compression tests, tensile tests, and drained triaxial compression tests. They added fibers with percentages of up to 0.9% and with fiber length (up to 36 mm). The results showed that the PET fibers improved the peak and ultimate strength of both soils. Also, the initial stiffness was not that changed by the fiber's inclusion, [18].

(Memon et al., 2019), added PET strips as reinforcement in the fine sandy soil (Passing No. 40). The strips of (35*8) mm were mixed in the soil with 0.5%, 1.0%, 1.5% and 2.0% by dry weight of the soil to investigate soil bearing strength. They found that the maximum dry density of the soil is decreasing with smaller value by the increasing the PET strip content in the soil. As well as, there is an increase in the CBR value with an increase in the PET strip reinforcement up to 1.5% and then there is decrease in the CBR value. Generally, they found that the reinforcement of the clayey soil with PET strips is a useful technique to improve the soaked bearing capacity of the soil, and in their research has been found that the CBR has been enhanced by two times of that plain soil by addition of 1.5% of the waste plastic strips. So that, the best recommended parentage is 1.5%, [19].

(Gangadhara et. Al, 2017), they added waste plastic bottle strips to red earth to as a reinforcing element to improve the strength characteristic. The red earth is classified as silt soil of low value of compressibility. The added percentages were (0, 1, 2, 3) %. It showed improvement in soil properties, [21].

(Alshkane, 2017), he reinforced sandy soil (passing sieve No. 4) with waste plastic bottles, in three different percentages of (1%, 2%, and 4.0) % by dry weight of sand with lengths of 16 mm and 8 mm. He found that inclusion of plastic fibers increased both angle of internal friction and cohesion. The short fibers gave less ductility than long fibers with the same amount of plastic-fibers but gave similar results of peak stresses. So that, the increase in cohesive property of soil so bearing capacity of soil increases and settlement as well as compressibility decreases. The best percentage was 1%, [22].

## 3. PROPOSED SYSTEM

### 3.1 Objective of the study

1. To analyze the characteristics of soil for different concentrations of 0%, 0.3%, 0.6%, 0.9% & 1.2% Polypropylene Plastic fiber mixed with it.
2. To evaluate engineering properties of Plastic fiber stabilized soil.
3. To study the outcome of Plastic fiber in soil stabilization, in the way to decrease the waste disposal problem, environmental pollution.

### 3.2 Methodology

Plastic fibers were obtained from waste cement bags (Polypropylene). After proper cleaning and air drying, the plastic bags were shred into fibers each of average thickness of 1mm and the length of 15mm. These plastic bags are usually considered to be waste materials.

1. Testing of black cotton soil
2. Testing of black cotton soil with plastic fiber with a additive percentages are 0%, 0.3%, 0.6%, 0.9% & 1.2%.
3. To compare them with and without plastic fiber stabilized soil
4. Conclusions, future scope

### 3.3 General

The Highway Research Board (HRB) classification of the soil strata like black cotton soil and are done using suitable sampling technique such as Core Cutter Method. To determine the characteristics like Grading by Sieve Analysis, Atterbergs Limits i.e Liquid limit using Casagrande Method, Plastic limit by rolling the sample to 3mm diameter thread, Optimum Moisture Content and Maximum Dry Density using Standard Proctor Test and also California Bearing Ratio. The determination of the properties such as liquid limit, plastic limit, optimum moisture content, maximum dry density and CBR value for different concentration of Geo synthetic material with black cotton.

## 4. RESULTS AND DISCUSSIONS

### 4.1. Liquid limit

1. The liquid limit of the soil alone was found to be 55%.
2. The liquid limit of the soil with addition of 0.3%, 0.6%, 0.9% and 1.2%, Plastic fiber by weight of soil is found to be 39%, 40%, 42% and 43% respectively.
3. The liquid limit of the soil with addition of 0.3%, 0.6%, 0.9% and 1.2%, Plastic fiber is found to be decreased by 29.09%, 27.27%, 23.636% and 21.81% respectively, when compared to liquid limit of soil alone.

### 4.2. Plastic limit

1. The plastic limit of the soil alone was found to be 27.27%
2. The plastic limit of the soil with addition of 0.3%, 0.6%, 0.9% and 1.2%, Plastic fiber by weight of soil is found to be 27.27%, 33.33%, 35.59 and 37.50% respectively.

3. The plastic limit of the soil with addition of 0.3%, 0.6%, 0.9% and 1.2%, Plastic fiber is found to be increases by 0%, 18.18%, 23.37% and 27.28% respectively, when compared to plastic limit of soil alone.

**4.3. Plasticity Index**

1. The plasticity index of the soil alone was found to be 27.73%.
2. The plasticity index of the soil with addition of 0.3%, 0.6%, 0.9% and 1.2%, Plastic fiber by weight of soil is found to be 11.73%, 6.67%, 6.41% and 5.5% respectively.
3. The plasticity index of the soil with the addition of 0.3%, 0.6%, 0.9% and 1.2% of Plastic fiber is found to be decreased by 57.69%, 75.94%, 76.88% and 80.165%.

**4.4 Standard Proctor Test**

1. The optimum moisture content (OMC) and maximum dry density (MDD) of soil alone was found to be 21.4% and 1.378 g/cc respectively.
2. The MDD of the soil with addition of 0.3%, 0.6%, 0.9% and 1.2%, Plastic fiber by weight of soil is found to be 1.401 g/cc, 1.419 g/cc, 1.564 g/cc and 1.377 g/cc respectively and the corresponding OMC is found to be 20.1%, 20.1%, 17.4% and 16.9% respectively.
3. The MDD of the soil with addition of 0.3%, 0.6%, 0.9% and 1.2%, Plastic fiber by weight of soil is found to be increased by 1.64%, 4.1%, 18.6% and 0% respectively and the corresponding OMC is decreased by 6%, 6%, 18.6% and 21.028% respectively.

**4.5 Caifornia Bearing Ratio (CBR) Test**

1. The CBR value of soil alone was found to be 1.82%
2. The CBR value of the soil with addition of 0.3%, 0.6%, 0.9% and 1.2%, Plastic fiber by weight of soil is found to be 3.49%, 3.96%, 5.41% and 3.96% respectively.
3. The CBR value of the soil with addition of 0.3%, 0.6%, 0.9% and 1.2%, Plastic fiber by weight of soil is found to be increased by 91.75%, 117.5%, 197.25% and 117.5%respectively.

## 5. CONCLUSIONS

The present experimental study concludes that the black cotton soil sample, based on Highway Research Board classification, is categorized as A-7-6 (4.549). The addition of waste plastic fibers significantly influences the soil's properties. The Maximum Dry Density (MDD) increases with plastic fiber addition up to 0.9% by weight, after which it starts to decline. Simultaneously, the Optimum Moisture Content (OMC) decreases as the fiber content increases. The California Bearing Ratio (CBR) test results indicate a significant improvement in the load-bearing capacity of the soil; the CBR value of the untreated soil is 1.82%, which increases to 5.41% after stabilization with the optimum plastic fiber content. This represents a 197.25% increase in CBR value, demonstrating the effectiveness of waste plastic fibers as a sustainable soil stabilizer for black cotton soil improvement.

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