Experimental Study on a Stabilization of Black Cotton Soil Using Waste Pet Plastic Bottles

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***Abstract*—The Earth's ecosystem depends heavily on soil, but growing pollution from plastic waste especially PET (polyethylene terephthalate) bottles pose a major threat to the environment. Because of its low stability and shear strength, black cotton soil which is notorious for having a high potential for shrinkage and swelling due to moisture variation presents serious construction challenges. In this study, shredded PET bottle waste (less than 0.5 mm in size) is added in different amounts (3%, 5%, and 7%) to stabilize black cotton soil. The goal is to address the management of plastic waste and enhance the engineering qualities of troublesome soil. Standard Proctor, Unconfined Compressive Strength, Moisture Content, Plastic Limit Test, Liquid Limit Test, California Bearing Ratio (CBR), Sieve Analysis, and Specific Gravity Test are examples of laboratory tests.**

***Index Terms*—Soil stabilization, Black cotton soil, Plastic waste, PET (Polyethylene Terephthalate, Shredded PET bottles, etc**

I. INTRODUCTION

Plastic waste accumulation has significantly increased as a result of the quick rise in plastic consumption, especially the extensive use of polyethylene terephthalate (PET) bottles. Because plastics have a limited capacity for natural degradation, the increase in non-biodegradable waste poses significant environmental risks. Innovative recycling and reuse techniques are therefore now crucial. Using plastic waste in civil engineering applications is one promising solution. Specifically, the use of plastic waste as a soil stabilizing agent is made possible by geotechnical engineering.

The presence of montmorillonite clay minerals is the main cause of the problematic swelling and shrinkage behavior of Black Cotton (BC) soil, which is frequently found in tropical areas like India. These characteristics frequently result in reduced ground stability,

Scope of the Present Study

- The current study focuses on using used PET plastic bottles as plastic strips to stabilize black cotton soil, which is notorious for having poor engineering qualities like low strength and high shrink-swell behavior. In order to assess improvements in: • Soil strength parameters (such as Unconfined Compressive Strength, or UCS, CBR); • Compaction characteristics; • Strength and Overall Soil Behavior; •By encouraging the reuse of plastic waste and improving subgrade performance for building and infrastructure projects, this research advances both economical ground improvement methods and sustainable waste management.

II. MATERIALS AND METHODOLOGY

Materials

PET (polyethylene-terephthalate) waste plastic bottle strips and expansive soil were the materials used in this study. The two materials were acquired locally.

Strips of PET raw plastic bottles measuring 5 mm in length and 0.5 mm in width were used. As a result, four distinct percentages 3%, 5%, and 7% by soil weight were applied.

Black cotton is grown in expansive, clay-rich soil that swells when wet and shrinks when dry, which leads to structural issues. It is stabilized with materials like fly ash, cement, or lime. These improve the soil's strength, reduce its plasticity, and regulate volume changes, making it suitable for construction.

EXPERIMENTAL STUDY

The following steps make up the experimental work:

1. Soil specific gravity 2. Atterberg Limits (soil index properties) (i) Liquid limit using Casagrande's equipment
3. Sieve analysis of particle size distribution
4. Making samples of reinforced soil.
5. Using the Proctor compaction test with and without reinforcement, the soil's maximum dry density (MDD) and matching optimum moisture content (OMC) are determined.
7. The Bearing Ratio Test in California.I) Wet II) Dry
8. Test of unconfined compression

I) soaked for 7, 14, and 28 days.

II) Unsoaked

III. METHODOLOGY

The study involved preparing a soil-plastic mix by oven-drying soil and passing it through a 4.75 mm sieve. Shredded PET plastic was added at 3%, 5%, and 7% by dry weight and uniformly blended. Tests were conducted in accordance with IRC:SP:72-2015 and IS 2720 standards. Index properties such as Liquid Limit (LL), Plastic Limit (PL), and Specific Gravity were determined using IS 2720 (Parts 3 and 5), while grain size distribution was assessed via sieve analysis (IS 2720 Part 4).

Compaction characteristics, including Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), were obtained using the Standard Proctor Test (IS 2720 Part 7). The California Bearing Ratio (CBR) test (IS 2720 Part 16) was performed on soaked (4 Days or 96 hrs) and unsoaked samples to evaluate bearing capacity. Unconfined Compressive Strength (UCS) tests (IS 2720 Part 10) were carried out on samples cured for 7, 14, and 28 days in a moisture-controlled environment. Results from treated samples were compared with plain soil to assess changes in Plasticity Index, MDD, OMC, CBR, and UCS, highlighting the impact of PET plastic inclusion on soil performance.

IV. RESULTS AND DISCUSSION

Using IS code books 2720 parts, the soil was categorized using index properties like Atterberg's limits, specific gravity, Standard proctor tests, California bearing ratio tests, and unconfined compression tests.

To conduct the tests, we used the codebooks listed below.

V. PROPERTIES OF BLACK COTTON SOIL SAMPLE

properties	result	limit	Relevant code
Liquid limit	27 %	40-100	IS 2720 Part 5
Plastic limit	30.5 %	-	IS 2720 Part 5
Specific gravity	2.57	2.65-2.8	IS 2720 Part 5
Unconfined compression test	0.031 N/mm^2	-	IS 2720 Part 10
Maximum dry density	1.51 g/cc	->1.59	IS 2720 Part 8

Optimum moisture content	20%	-	IS 2720 Part 8
California bearing ratio CBR	16% & 4.80%	-	IS 2720 Part 8
Sieve analysis	Cu= 9 Cc= 1.56	-	IS 2720 Part 5

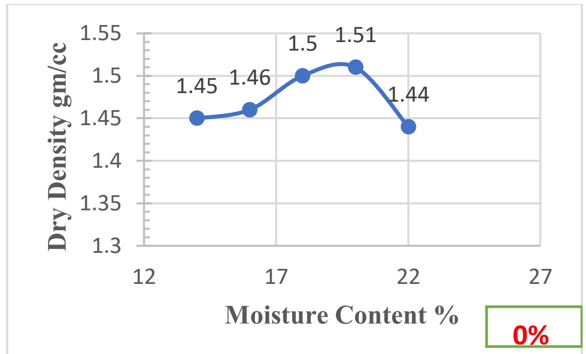
PET plastic %	MDD g/cc	OMC %
0	1.51	20
3	1.53	19
5	1.55	19
7	1.57	18

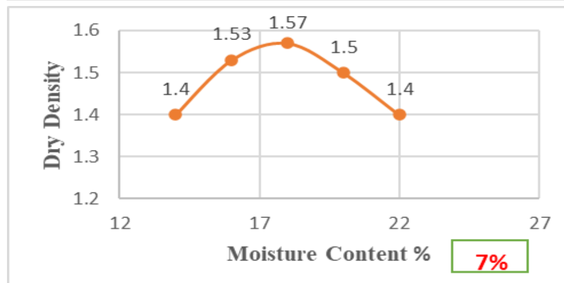
1.Standard Proctor Compaction

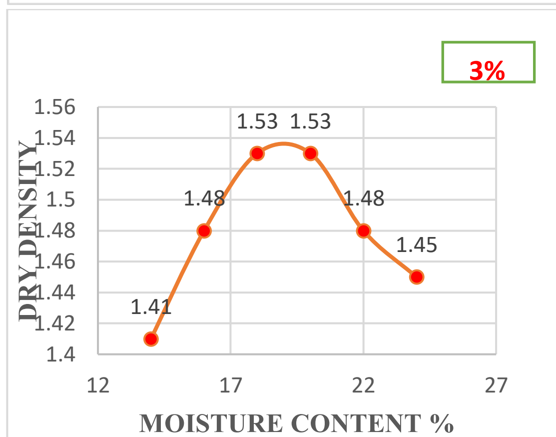
In the Standard Proctor Test, three layers of soil are compacted in a cylindrical mold, and each layer is subjected to 25 blows from a 2.5 kg rammer that is dropped from a height of 31 cm. To find the maximum dry density (MDD) and optimum moisture content (OMC), the process is repeated over roughly five trials with different moisture contents. A cylindrical metal mold measuring 10.15 cm in internal diameter and 11.7 cm in height, a detachable base plate, a collar that is 5 cm high, and a 2.5 kg rammer make up the experimental setup. The Light Weight Proctor Test, administered with and without reinforcement, is part of our investigation. By the weight of the soil sample, reinforcement is added at rates of 3%, 5%, and 7%.

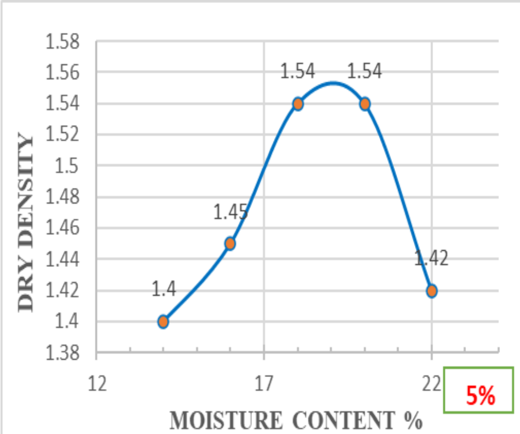
1.Without reinforcement

Table 1: Calculation of Optimum Moisture Content and Maximum Dry Density 0%,3%,5%,7% Reinforcement

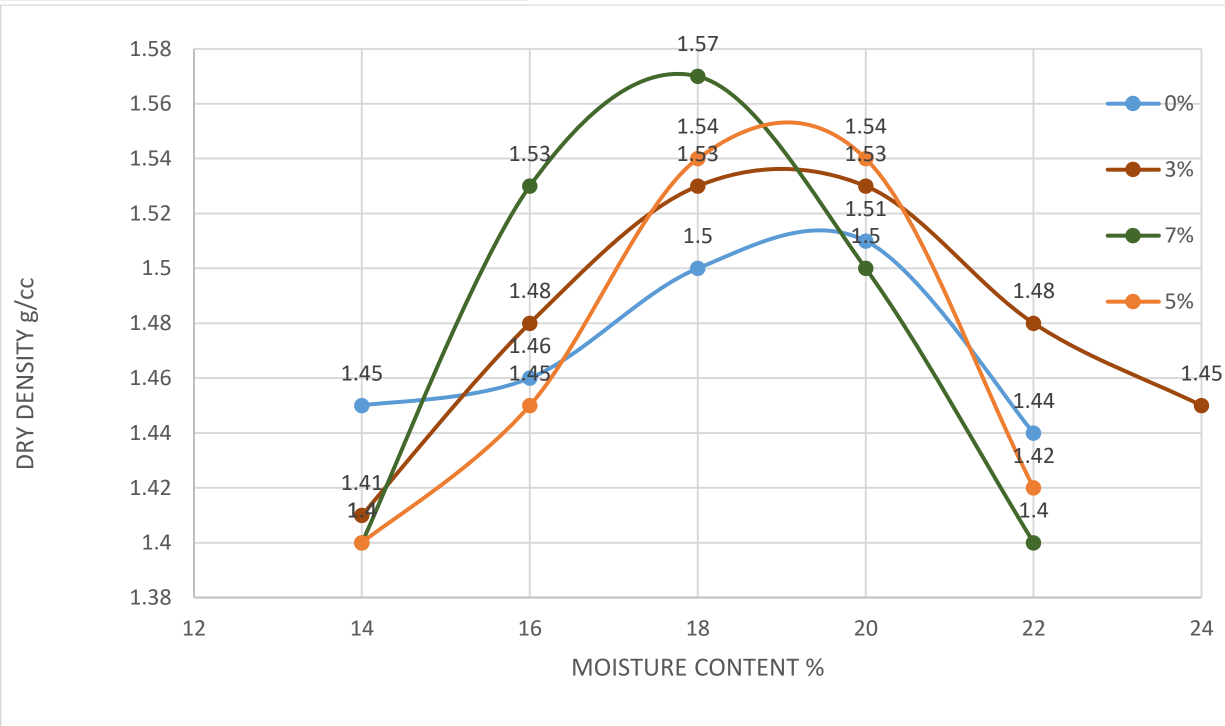








1.2 Comparative Analysis of Proctor Tests



Graph Plot between Water Content and Dry Density for No Plastic, Plastic with 0% MDD =1.51 g/cc, OMC = 20%, 3% MDD= 1.53 g/cc, OMC =19 %, 5% MDD= 1.55, OMC = 19 %, 7% MDD = 1.57 %, OMC = 18 %.

According to the results of the SPT test, the best results are obtained when 7% of waste PET bottles that have been ground to a size smaller than 1 mm are combined with the soil. Compared to traditional stabilizers, using used PET bottles as a stabilizing agent is a more economical way to stabilize black cotton soil.

2 CALIFORNIA BEARING RATIO (CBR) TEST

A cylindrical plunger with a cross-sectional area of 5 cm² is pushed into a soil sample as part of the California Bearing Ratio (CBR) load penetration test. The load needed to reach particular penetration depths is noted during the test. The term "test load" refers to this measured resistance. The standard load, for comparison, is the load needed to accomplish the same penetration in a typical crushed stone sample. The following formula is used to determine the CBR value:

CBR = (Test Load / Standard Load) × 100

In our investigation, we evaluated both soaked and unsoaked soil samples. Additionally, tests were conducted with and without the inclusion of reinforcement. The reinforcement material was added at varying percentages by weight specifically, 0%, 3%, 5%, and 7%.

2.1 UNSOAKED SAMPLE:

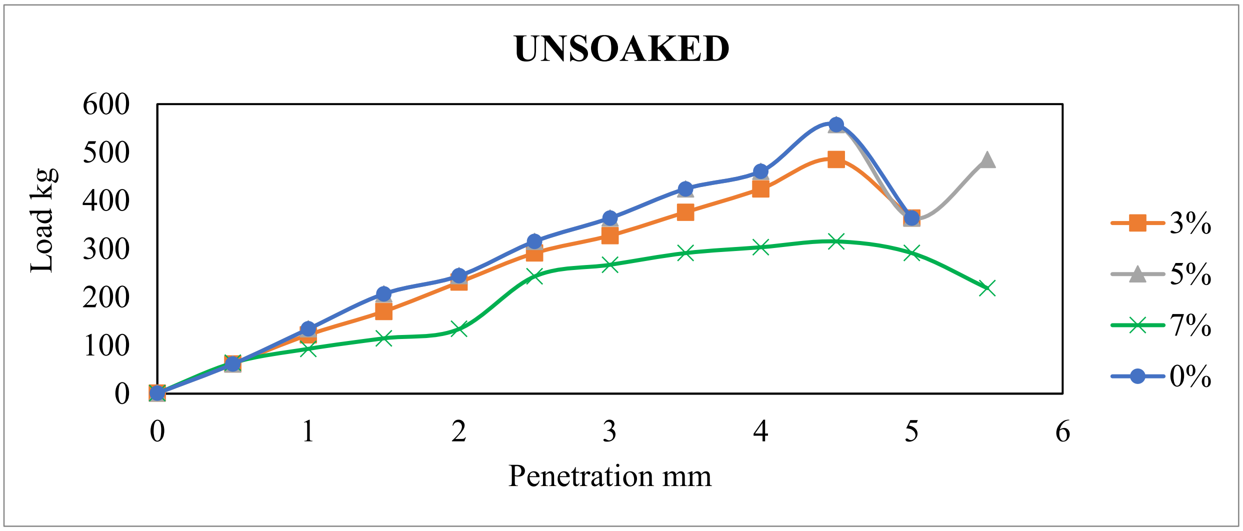
% of Plastic Content	0	3	5	7
CBR Value %	16	21	23	17

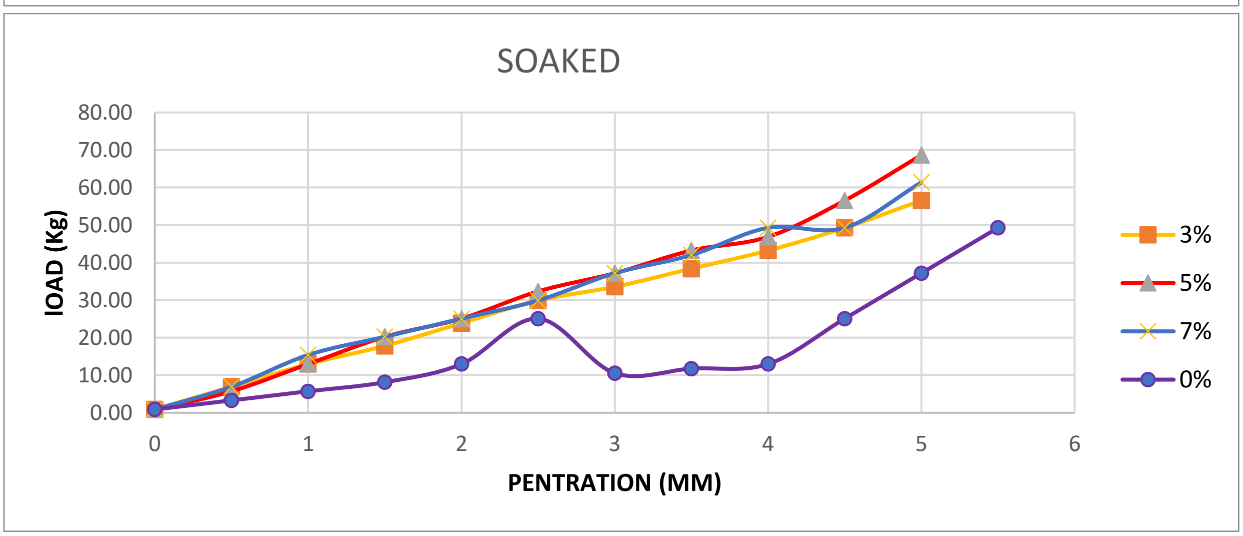
2.2 SOAKED SAMPLE

Before testing, we soaked the soil samples in water for four days or 96 hrs. By simulating the worst-case scenario of wetting, this soaking enables the sample to become saturated. Usually, subgrade reaction modulus calculations and pavement design use the soaked CBR value.

% of Plastic Content	0	3	5	7
CBR Value %	2.39	2.75	3.34	2.98

The CBR values indicate improved load-bearing capacity with the incorporation of PET plastic, with the highest value at 5% PET content.





The unsoaked CBR value is typically higher than the soaked CBR value in the California Bearing Ratio (CBR) test. The reason for this discrepancy is that soaking a soil sample for a long time—usually four days—decreases its bearing capacity because it swells and becomes less frictional. The soaked CBR test replicates a saturated or wet condition, which is a more realistic scenario for pavement design, whereas the unsoaked CBR test replicates dry conditions.

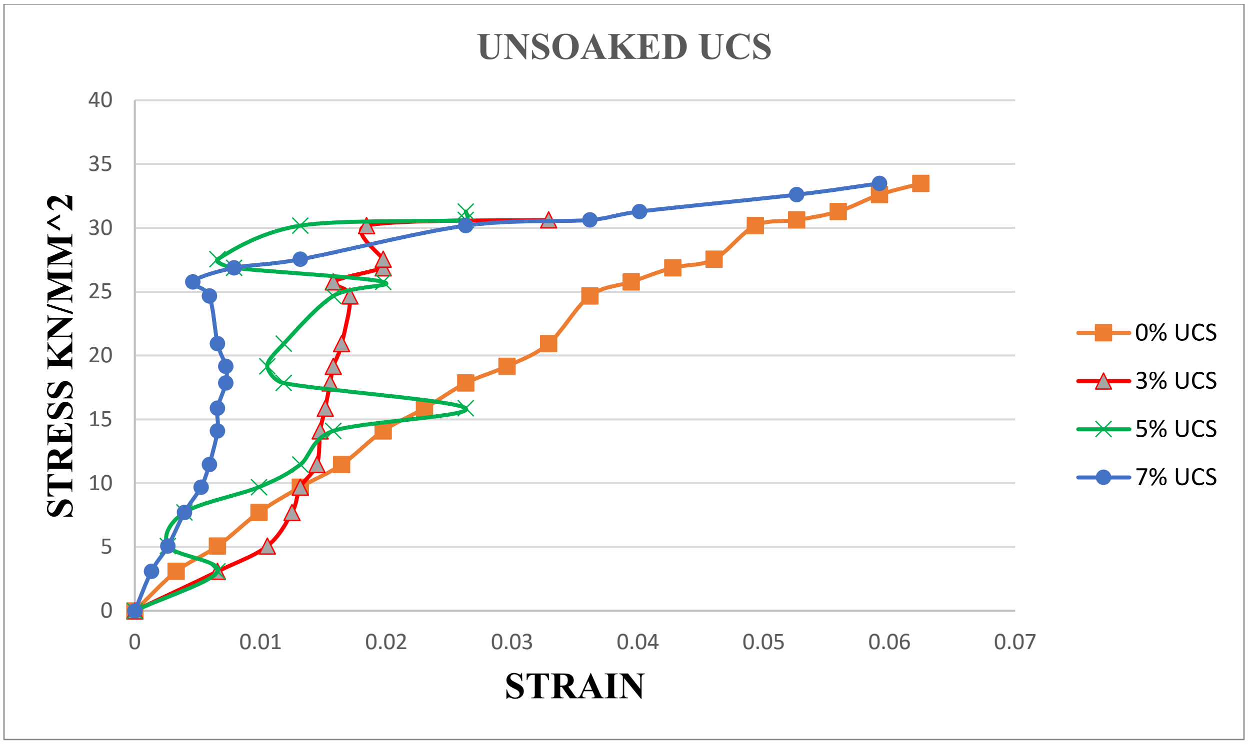
Up to 5% PET content raises the CBR value, at which point the soil receives the best reinforcement possible because of enhanced internal friction and particle interlocking. Excess PET reduces the strength of the soil by upsetting its structure after 5%. Consequently, the ideal content percentage for enhancing the unsoaked CBR is 5%.

3.UNCONFINED COMPRESSION STRENGTH (UCS) TEST:

A basic laboratory technique for determining the shear strength of cohesive soils, such as Black Cotton Soil (BCS), is the Unconfined Compression Strength Test (UCS). The maximum axial stress that a soil sample can sustain without experiencing lateral confinement is determined by this test. The UCS sheds light on how the addition of plastic waste affects soil strength over various curing times in the case of BCS stabilized with different percentages of Polyethylene Terephthalate (PET) plastic, specifically 3%, 5%, and 7% with soaked and unsoaked samples. In one study, samples were cured for 7, 14, and 28 days to examine the effects of adding 3%, 5%, and 7% PET plastic (particle size <0.5 mm) to BCS. The findings showed that

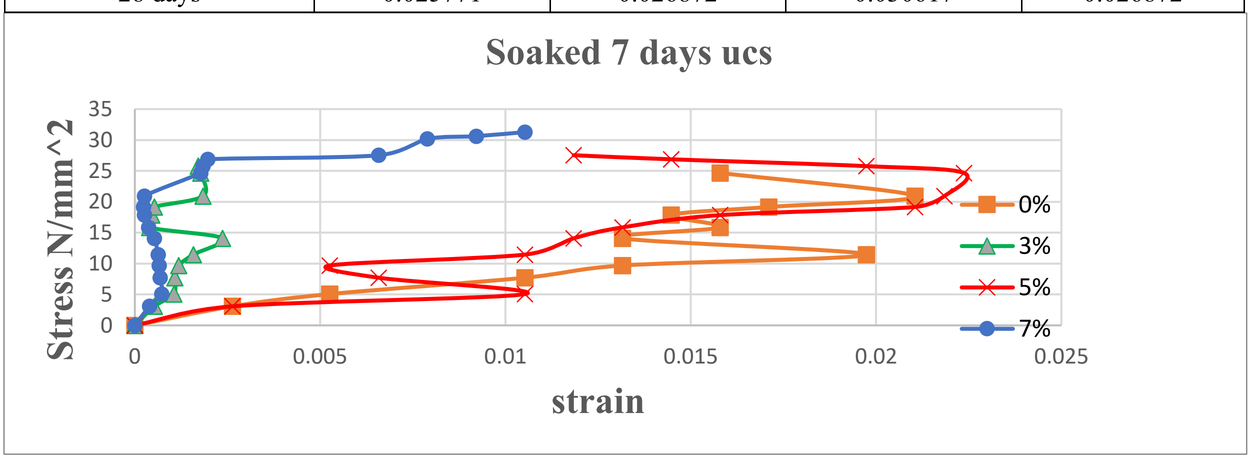
3.1 UNSOAKED SAMPLES

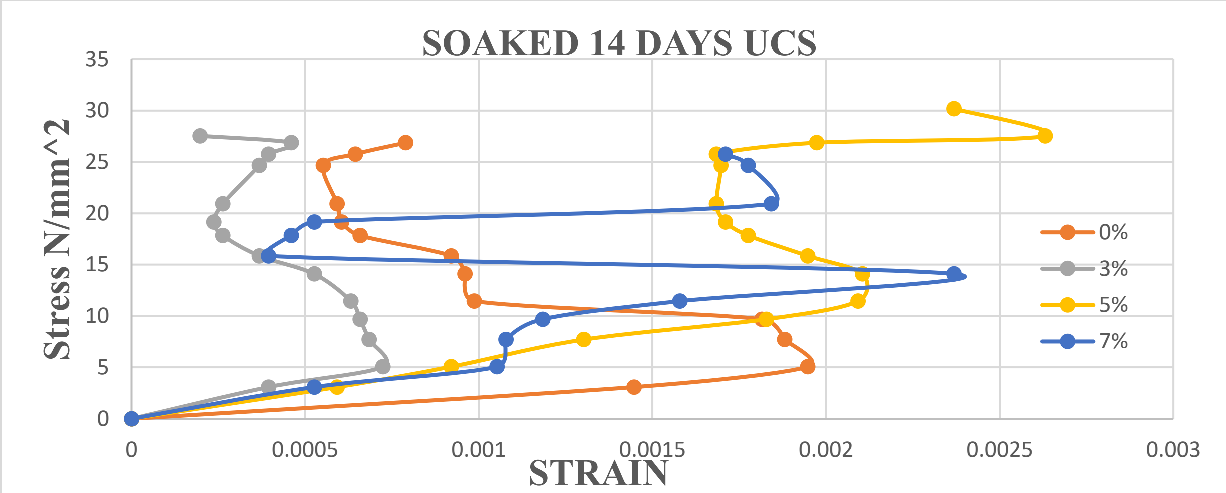
% of Plastic content	0%	3%	5%	7%
UCS Value N/mm^2	0.027533	0.030617	0.031278	0.030176

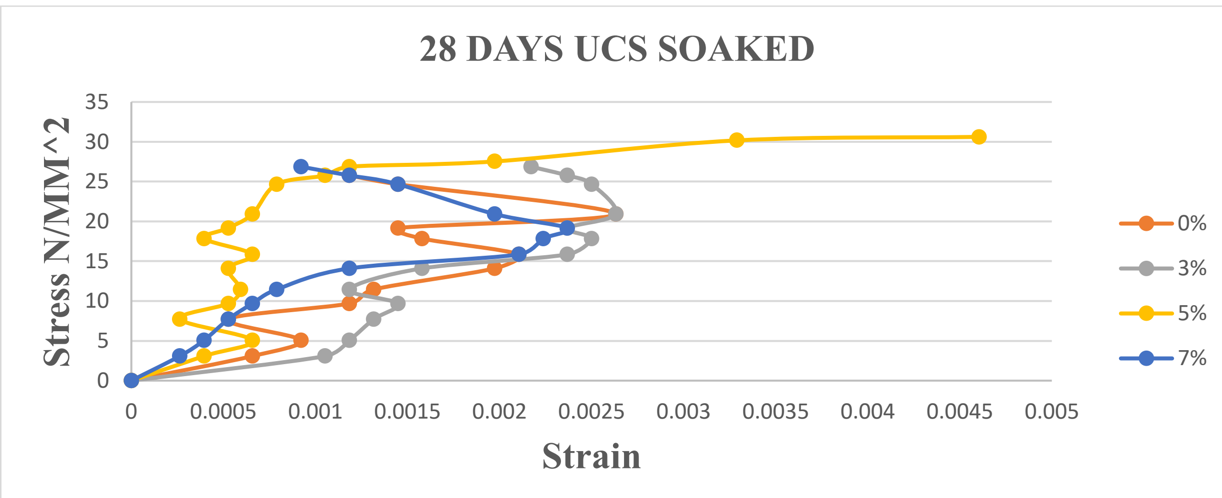


3.2 SOAKED SAMPLES

% of Plastic content	0%	3%	5%	7%
UNCONFINED COMPRESSION STRENGTH TEST N/MM^2				
7 days	0.02467	0.025771	0.027533	0.03348
14 days	0.026872	0.027533	0.030176	0.027533
28 days	0.025771	0.026872	0.030617	0.026872







The UCS values indicate that adding PET plastic increases soil strength, reaching a peak at 5% PET content. After this, a minor reduction in strength was noted at 7% PET.

3.3 Observations on Soaked vs. Unsoaked Conditions

1.UNSOAKED

When plastic content is increased up to 5%, the unsoaked samples' UCS values show a slight increase in strength, going from 0.027533 N/mm² (0%) to 0.031278 N/mm² (5%). The UCS value, however, slightly drops to 0.030176 N/mm² at 7% plastic content, suggesting that 5% is the ideal plastic content for strength enhancement. After this, adding more plastic could result in a slight decrease in strength, perhaps as a result of inadequate bonding or too much plastic interfering with soil cohesiveness.

2 SOAKED

• After seven days, peak strength was noted at 7% plastic content: 0.03348 N/mm²

• At 28 days, the strongest material was 5% plastic: 0.030617 N/mm²

• Trend: Up to 5-7 percent plastic content usually results in an increase in strength; after that, it may decrease or fluctuate.

• The ideal plastic content is 5%, which over time provides steadily greater strength.

VI. CONCLUSIONS

The present study's findings allow for the following conclusion to be drawn:

1 To assess the increase in the bearing capacity of foundations made from waste PET bottles, a model Unconfined Compressive Strength (UCS) test was conducted.

2. The test results showed that adding waste PET bottles to the soil significantly increased its load-bearing capacity.
3. In light of these results, adding PET bottles to the soil is advised as a way to increase its overall strength.
4. It is also suggested that by increasing soil stability, the use of waste PET bottles in foundation soil may help make the soil more earthquake resistant.
5. Although end-of-life plastics, like PET bottles, are regarded as waste, they can be recycled into foundation soil with clay.

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