Soil Stabilisation Using Plastic Waste and Geosynthetic Fibre

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Abstract. The reuse and recycling of plastic waste remain significantly below desirable levels, with uncollected plastic waste constituting 40% of the total, often ending up in landfills, clogging water bodies, polluting streets, and contributing to the plastic crisis. While the Indian government reports a 60% recycling rate, data from the Centre for Science and Environment (CSE), based on statistics from the Central Pollution Control Board (CPCB), indicate that only 12% of plastic waste is actually recycled. Expansive clay soils, characterized by swelling and shrinking behavior, pose significant challenges to structural stability. Recent studies have explored the use of plastic and geosynthetic waste for soil improvement. This study aims to enhance the stabilization of expansive clay soils through the incorporation of plastic and geosynthetic wastes. Small plastic strips measuring 10 mm × 15 mm were added to the soil in varying proportions. The research involves determining the initial soil properties and comparing the California Bearing Ratio (CBR) test results of untreated and treated soil to evaluate the effectiveness of the stabilization approach.

Keywords: Soil Stabilization, Expansive Clay Soils, Plastic Strips, Geosynthetic Fibre

1 Introduction

Soil stabilization is a technique that is used to improve the strength, durability, and other properties of soil. It involves the addition of certain materials or chemical agents to the soil to enhance its physical and mechanical properties. Soil stabilization aims to make the soil suitable for specific engineering use, such as building roads, runways, embankments, or foundations.

The materials used for soil stabilization can vary depending on the type of soil and the engineering application. Common materials include cement, lime, fly ash, bitumen, and various chemical agents. These materials are mixed with the soil in varying quantities and using different techniques, such as blending, injection, or compaction.

Soil stabilization offers numerous benefits, including reducing soil erosion, increasing soil strength and stability, improving the soil's load-bearing capacity, and enhancing the durability of soil structures. It is a cost-effective solution for many soil-

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related engineering problems and is widely used in construction and infrastructure projects.

1.1 Importance of Soil Stabilization

Soil stabilization is a crucial aspect of civil engineering, which involves enhancing the properties of soil to make it suitable for construction purposes. One of the most pressing issues of our time is the growing amount of plastic waste that is polluting our environment. One innovative solution to address these issues is using plastic waste and geosynthetic fibre to stabilize soil.

This soil stabilization project aims to use plastic waste and geosynthetic fibre to enhance the properties of soil and make it more suitable for construction. Plastic waste will not only provide a sustainable solution to the growing problem of plastic waste but will also help reduce the use of traditional construction materials. Geosynthetic fibres are synthetic materials used to reinforce soil and improve its strength and stability. Together, plastic waste and geosynthetic fibre can be used to create a composite material that will enhance the mechanical properties of soil and make it suitable for a wide range of construction applications.

This project focuses on the collection and processing of plastic waste into suitable sizes, which will then be combined with soil and geosynthetic fibers. The resulting composite material will undergo testing to evaluate its engineering properties, including strength, deformation, and permeability. The primary objective is to develop a sustainable and cost-effective method for soil stabilization, suitable for various construction applications.

By addressing the issue of plastic waste while enhancing soil stabilization techniques, this study aims to contribute to environmentally sustainable practices in infrastructure development, ensuring safer and more efficient construction.

1.2 Use of Plastic & Geosynthetics in Soil Stabilization

Plastic and geosynthetics are two commonly used materials for soil stabilization, including in red soil. While both materials can be effective, there are some differences in their properties, advantages, and disadvantages. Plastic sheets or films are typically used for soil stabilization by forming a barrier between the soil and the surface above it. This can help prevent erosion and the loss of soil particles. However, plastic sheets do not provide any additional structural support to the soil, and they can be susceptible to damage from weather, UV radiation, and other environmental factors. Additionally, the disposal of plastic sheets can have negative environmental impacts.

On the other hand, geosynthetics are synthetic materials that are designed specifically for soil stabilization. They are typically made of materials such as polypropylene, polyester, or other polymers, and they can be engineered to have specific properties such as tensile strength, durability, and permeability. Geosynthetics can provide additional support to the soil, increasing its load-bearing capacity and resistance to deformation. They can also help control soil erosion, stabilize embankments, and improve drainage. Geosynthetics can be more durable than plastic sheets, and they can be reused or recycled, making them a more sustainable option. Overall, while plastic sheets may be suitable for some soil stabilization applications, geosynthetics offer more comprehensive and effective solutions for stabilizing red soil. Geosynthetics can provide both structural and erosion control benefits, and they can be customized to meet specific project requirements. Additionally, they can be more cost-effective and sustainable in the long run.

2 Materials Used

- Red soil
- Plastic waste (PET bottles)
- Geosynthetic fibre

Fig. 1. Geosynthetic fibre and Plastic strips

3 Materials Used

The study involved characterizing the soil sample through tests such as particle size distribution, Atterberg limits, and specific gravity. The sample was sieved to remove contaminants and unwanted materials before being prepared for testing. Sieve analysis was carried out to determine particle size distribution. Using Casagrande's apparatus, the Atterberg limit test measured the plastic limit, liquid limit, and plasticity index of the soil. Specific gravity was assessed in the geotechnical laboratory. Additionally, a CBR test was performed to evaluate soil strength. The sample was mixed with plastic bottle strips (10 mm x 15 mm) and geosynthetic fibers (15 mm length).

3.1 Material Mixing Method and Proportions

Plastic strips and geosynthetic fibers, intended to function as soil reinforcements, were mixed with the soil in three different proportions by weight as shown in Table 1. After characterizing the materials, the plastic bottle strips and geosynthetic fibers were incorporated into the soil sample. The effects of adding these materials to red soil were evaluated using the Standard Proctor Compaction Test, Direct Shear Test, and California Bearing Ratio (CBR) Test.

Table 1. Treatment levels.

Strip Size (mm)	Treatment Level (%)
	1
10 X 15	2
	3

4 Results and Discussion

4.1 General

In the present study, all the needed soil particle tests are conducted. The changes in soil stabilization are observed. Grounded on the results, conclusions are drawn to understand the variations in soil stabilization.

4.2 Sieve Analysis

In the present study, all the needed soil particle tests are conducted. The changes in the curve (Fig.2) represents the soil that contains particles of different sizes in good proportion such soil is called well graded soil or uniformly graded soil (Gravel or Sand).

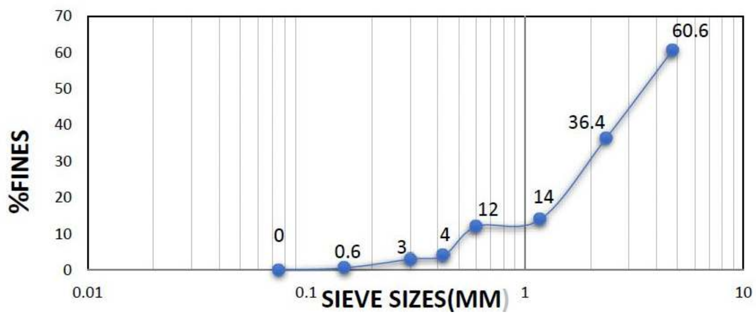

Fig. 2. Sieve analysis curve for the soil sample

For the soil sample the uniformity measure, Cu = 7.33.
The measure of the curve, Cc = 1.43.
As Cu is lesser than 6(Cu> 6) & Cc is between 1 to 3 (Cc- 1 to 3) the below soil is well-graded sand.

4.3 Specific Gravity

The soil samplehas the specific gravity as 2.51.

For theset mixture of soil with 1% plastic waste &0.25% geosynthetic fibre,the specific gravity is 2.65.

From the results specific gravity of theset mixture is increased, an increase in specific gravity can have counteraccusationsfor soil strength and stability. Heavier soils may be more resistant todistortion or erosion, but they may also be moredelicate toshovel or work with. It's important toestimate the specific gravity of soil in any engineering or constructiondesign to ensure that the soilparticles are applicable for the intended use.

4.4 Liquid Limit

For the soil sample, The liquid limit value is 29.85% attained at standard 25 blows from the graph(Fig.3).

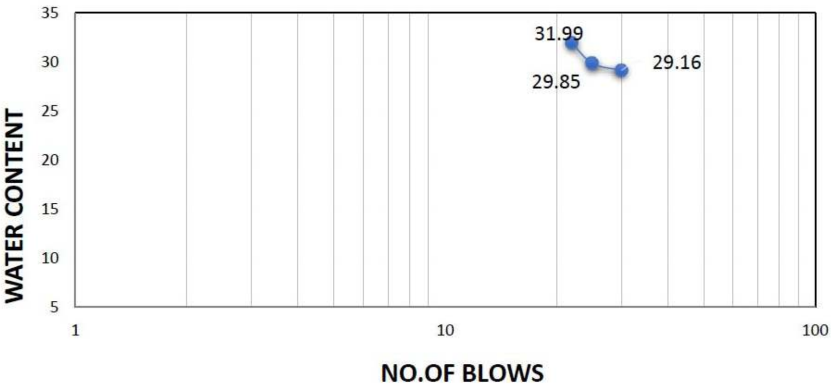

Fig. 3. Liquid Limit for the soil sample

For the set mixture of soil with 1% plastic waste &0.25%geosyntheticfibre, the liquid limit value is 27.35% attained at standard 25 blows from the graph (Fig.4).

The results show a decrease in the liquid limit with the addition of plastic waste and geosynthetic fibers. This reduction indicates that the soil has become more stable, less prone to deformation, and more resistant to water erosion, contributing to a more efficient and sustainable soil stabilization design.

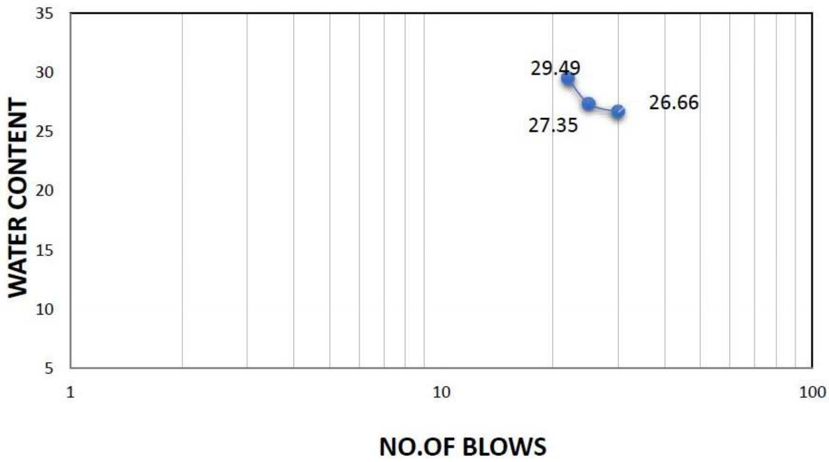

Fig. 4. Liquid Limit for the prepared mixture

4.5 Plastic Limit

The soil sample has an average plastic limit of 20%.

For the set mixture of soil with 1% plastic waste &0.25%geosyntheticfibre, the average plastic limit is 18%.

From the results plastic limit of the set mixture is dropped, a drop in plastic limit due to the addition of plastic waste and geosynthetic fibres can indicate that the soil has come more stable and less susceptible to distortion. This can lead to lesser load-bearing capacity and better durability. Also, the reduction in plastic limit can upgrade the soil's resistance to water erosion.

4.6 IS Compaction

The IS Compaction Test was conducted to determine the optimum moisture content (OMC) of the soil sample. The test revealed an OMC of 13% for the untreated soil. For the soil mixture containing 1% plastic waste and 0.25% geosynthetic fibers, the IS Compaction Test showed an OMC of 14%.

The results indicate an increase in OMC for the treated mixture. This rise in OMC due to the addition of plastic waste and geosynthetic fibers may suggest a potential concern or limitation in the overall design's efficiency.

4.7 Direct Shear

For the soil sample, to know the shear strength of the soil Direct Shear test is done. From the results (Fig.5), the shear stress of the soil is 0.5512 kg/cm^2.

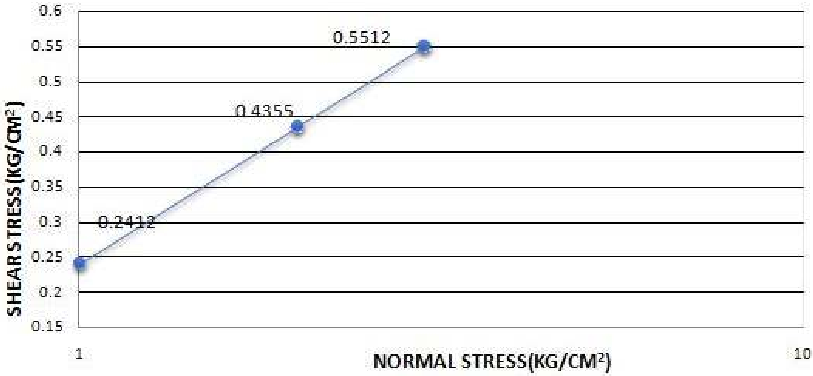

Fig. 5. Shear Stress for the soil sample.

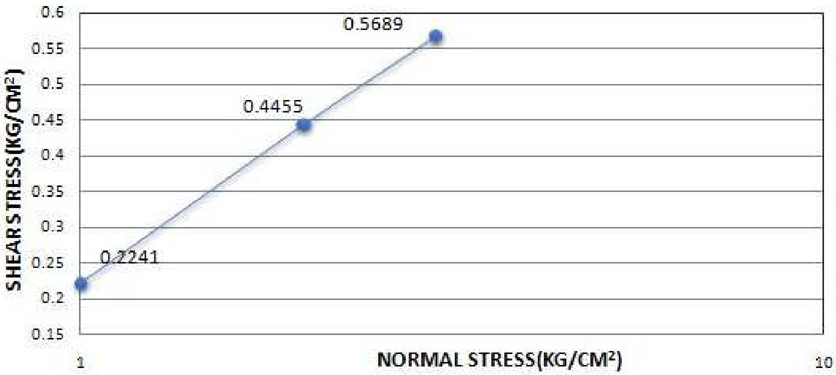

Fig. 6. Shear Stress for prepared mixture

For the set mixture of soil with 1% plastic waste &0.25% geosynthetic fibre, to know the shear strength of the soil Direct Shear test is done.

From the results (Fig.6), the shear stress of the set mixture is 0.5689 kg/ cm2.

From the results, the shear stress is increased for the set mixture, and an increase in shear stress in a soil stabilization design by using plastic waste and geosynthetic fibres indicates that the soil's shear strength has increased. This means that the soil can now repel advanced situations of stress without distorting, performing with lesser stability and load-bearing capacity. Also, the increase in shear stress can indicate an enhancement in the soil's durability and resistance to erosion.

4.8 California Bearing Ratio (CBR)

For the soil sample: The CBR value is 2.34%.

As mentioned in Table 2, for the prepared mixture of soil with 1% plastic waste & 0.25% geosynthetic fibre (Fig.7): The CBR value is 3.93%.

For the prepared mixture of soil with 1% plastic waste & 0.50% geosynthetic fibre: The CBR value is 1.60%.

For the prepared mixture of soil with 1% plastic waste & 0.75% geosynthetic fibre: The CBR value is 1.29.

For the prepared mixture of soil with 1% plastic waste & 0.25% geosynthetic fibre in soaked condition: The CBR value is 2.80%.

Table 2. CBR values for the soil and the prepared mixture

A mixture prepared of soil with plastic and geosynthetics	**CBR test results (%)**
Red Soil	2.34
1% plastic and 0.25% geosynthetic fibre (unsoaked)	23.93
1% plastic and 0.25% geosynthetic fibre (soaked)	2.80
1% plastic and 0.50% geosynthetic fibre	1.60
1% plastic and 0.75% geosynthetic fibre	1.29

As shown in Table 3, for the prepared mixture of soil with 2% plastic waste & 0.50% geosynthetic fibre: The CBR value is 1.43%.

For the prepared mixture of soil with 3% plastic waste & 0.75% geosynthetic fibre: The CBR value is 0.89%.

Table 3. CBR values for the mixtures which are twice and thrice the ultimate mixture

A mixture prepared of soil with plastic and geosynthetics	**CBR test results (%)**
2% plastic and 0.50% geosynthetic fibre	1.43
3% plastic and 0.75% geosynthetic fibre	0.89

Table 4 provides a detailed comparison of the properties of natural soil and the prepared soil mixture. The analysis reveals that the soil mixture demonstrates enhanced physical and mechanical properties, indicating improved performance. These improvements may be attributed to the optimized composition of the mixture, which likely enhances its strength, stability, and other critical characteristics compared to the natural soil.

Table 4. Comparison of properties of soil with the prepared mixture

Properties	Red Soil	A mixture prepared of soil with 1%plastic & 0.25%geosynthetics
Specific gravity	2.51	2.65
Liquid Limit	29.85%	27.35%
Plastic Limit	20%	18%
Sieve Analysis	C_u>6 & C_c - 1 to 3	C_u>6 & C_c - 1 to 3
Shear Stress	0.5512 kg/cm^2	0.5689 kg/cm^2
Optimum Moisture Content	13%	14%

Fig. 7. Prepared mixture sample

5 Conclusions

Soil stabilization involves enhancing the engineering properties of soil through the addition of various materials. In this project, plastic waste and geosynthetic fibers were utilized as stabilizers. A mixture containing 1% plastic waste and 0.25% geosynthetic fiber was prepared, and its properties—such as shear strength, California Bearing Ratio (CBR), Optimum Moisture Content (OMC), specific gravity, liquid limit, and plastic limit—were analyzed. The results were compared with untreated soil, revealing improvements in properties like shear strength, CBR, OMC, and specific gravity, while liquid limit and plastic limit showed a decrease. This improvement demonstrates that the mixture enhances soil strength and stability, making plastic waste and geosynthetic fibers effective stabilizers suitable for construction applications.

The decrease in liquid limit and plastic limit can be attributed to the inclusion of plastic waste, which likely reduces the soil's plasticity index. However, this reduction does not significantly impact the overall performance of the stabilized soil.

In conclusion, the use of a mixture containing 1% plastic waste and 0.25% geosynthetic fibers has proven to be an eco-friendly, cost-effective, and practical approach for improving soil properties. Despite its potential, further research and testing are recommended to thoroughly evaluate its long-term performance and durability.

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