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Soil Stabilization Using Plastic Waste

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Abstract: *Soil stabilization is an essential technique in civil engineering to enhance the strength and durability of weak soils. This study investigates the use of plastic waste as a stabilizing agent. Plastic waste was mixed with natural soil, and laboratory tests such as Atterberg Limits and California Bearing Ratio (CBR) were conducted. The results show that the addition of plastic reduces moisture content and plasticity while significantly improving the strength of soil. This method not only enhances soil properties but also provides an eco-friendly solution for plastic waste disposal.*

Keywords: soil stabilization, Plastic waste, weak soil ,Durability, Moisture Content

I. INTRODUCTION

Background

Soil stabilization is a fundamental technique used in civil engineering to improve the strength, stability, and load-bearing capacity of soil, enabling it to safely support various structures such as roads, buildings, and pavements. Weak or loose soil frequently leads to significant engineering problems including excessive settlement, cracking, and premature failure of pavements and foundations. Traditional soil stabilization methods typically employ materials such as cement, lime, fly ash, or chemical additives, which can be expensive and may have environmental drawbacks

In recent years, there has been growing interest in utilizing waste materials for soil stabilization as a sustainable alternative. Among these materials, plastic waste has emerged as a promising stabilizing agent due to its availability, durability, and potential to address the global plastic pollution crisis. India generates approximately 3.5 million tonnes of plastic waste annually, with a significant portion remaining uncollected and improperly disposed, causing severe environmental degradation

Plastic Waste and Environmental Concerns

Plastic waste disposal represents one of the most pressing environmental challenges of the 21st century. Plastics are non-biodegradable materials that persist in the environment for hundreds of years, contributing to soil contamination, water pollution, and harm to wildlife. The improper disposal of plastic waste in landfills and open areas has created urgent demand for innovative recycling and reuse strategies.

Using plastic waste in civil engineering applications, particularly soil stabilization, offers a dual benefit: it improves soil engineering properties while simultaneously reducing the environmental burden of plastic waste. This approach aligns with the principles of sustainable development and circular economy

Mechanism of Soil Stabilization with Plastic Waste

When shredded plastic is mixed with soil, several mechanisms contribute to improved soil properties. The plastic particles act as discrete reinforcing elements that increase the friction between soil particles and create a three-dimensional network within the soil matrix. This reinforcement mechanism enhances the shear strength and load-bearing capacity of the soil Additionally, since plastic is hydrophobic (water-repelling), it reduces the overall water absorption capacity of the soil mixture, leading to improved stability under moisture variations.

Research Significance

This study is significant because it provides practical experimental evidence for the effectiveness of plastic waste as a soil stabilizer, specifically focusing on the optimal percentage of plastic content for maximum improvement. The research contributes to the existing body of knowledge on sustainable construction materials and offers a viable solution for managing plastic waste while addressing geotechnical engineering challenges faced at construction sites

Objectives

The primary objectives of this experimental investigation are:

- To evaluate the effect of plastic waste on the engineering properties of soil
- To determine the optimal percentage of plastic waste for effective soil stabilization
- To compare the performance of natural soil with plastic-stabilized soil through laboratory testing
- To assess the improvement in California Bearing Ratio (CBR) value with plastic waste addition
- To analyze changes in Atterberg limits (Liquid Limit and Plastic Limit) due to plastic incorporation
- To provide a cost-effective and environmentally sustainable solution for soil stabilization
- To contribute to plastic waste management by demonstrating a practical application in civil engineering

Need for the Study

Weak Soil at Construction Sites: Many construction sites, particularly in urban and semi-urban areas of Maharashtra, encounter weak or expansive soils that cannot safely support structures without ground improvement techniques. These soils require stabilization to prevent settlement, foundation failure, and structural damage.

Plastic Waste Generation: India generates massive quantities of plastic waste annually, estimated at approximately 3.5 million tonnes, with generation rates continuously increasing due to urbanization and changing consumption patterns. Disposal of this waste poses significant environmental and public health challenges

Non-Biodegradability of Plastics: Plastic waste does not decompose easily and can persist in the environment for hundreds of years, leading to soil contamination, water pollution, blockage of drainage systems, and harm to terrestrial and aquatic ecosystems.

Cost-Effective Construction: Traditional soil stabilization materials such as cement and lime can be expensive and energy-intensive to produce. Using plastic waste as a stabilizer offers a low-cost alternative that reduces construction expenses while achieving comparable or superior performance.

Sustainable Development: The construction industry is under increasing pressure to adopt sustainable practices. Utilizing waste materials in construction aligns with the United Nations Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities) and SDG 12 (Responsible Consumption and Production).

Dual Environmental Benefit: This approach addresses two environmental problems simultaneously—it improves soil strength for safe construction and reduces plastic waste accumulation in the environment, creating a circular economy model.

Materials Used

The materials used in this study consist of natural soil, shredded plastic waste, and water, all of which play an important role in improving the engineering properties of soil. The natural soil was collected from a selected site and was first air-dried to remove natural moisture. It was then cleaned and passed through a sieve to eliminate coarse particles, stones, and organic impurities, ensuring a uniform and fine soil sample for testing. The plastic waste used in the study is a non-biodegradable material, which was collected, cleaned, and cut into small shredded pieces to ensure proper mixing and interaction with soil particles. The smaller size of plastic helps in better distribution and enhances the bonding within the soil matrix.

For stabilization, plastic waste was added at an optimum proportion of 3% by weight of dry soil, based on experimental considerations. In the laboratory, 250 g of dry soil was taken, and 7.5 g of shredded plastic was accurately weighed and mixed with the soil. The mixing process was carried out thoroughly to achieve a homogeneous and uniform blend, ensuring that plastic particles were evenly distributed throughout the soil mass. Water was then added slowly in small quantities while mixing to reach the desired moisture content required for compaction and testing procedures.

This combination improves soil behavior by reducing its plasticity and water absorption capacity, as plastic does not absorb water. It also increases the strength and load-bearing capacity of the soil by acting as a reinforcing material within the soil structure. The selected proportion of 3% provides a balance between improved strength and workability, making the stabilized soil suitable for practical applications such as subgrade layers in road construction and other civil engineering works.

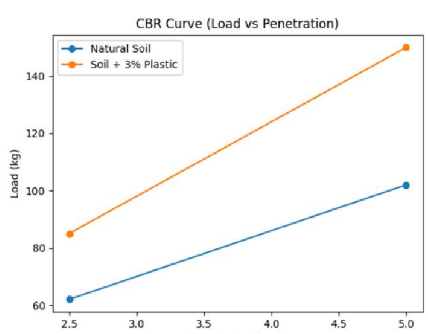
II. METHODOLOGY

The methodology of this study involves a systematic laboratory procedure to evaluate the effect of plastic waste on soil stabilization. First, the natural soil sample was collected from the site, air-dried, and sieved to remove coarse particles and impurities. The required quantity of soil was then weighed, and shredded plastic waste (3% by weight) was added to it. Both materials were mixed thoroughly to obtain a uniform and homogeneous mixture. Water was gradually added to achieve the desired moisture content for proper compaction. After preparation of the sample, standard laboratory tests were conducted, including Atterberg Limits (Plastic Limit and Liquid Limit) and California Bearing Ratio (CBR) test. The results obtained from the stabilized soil were then compared with those of natural soil to analyze the improvement in engineering properties such as strength, plasticity, and load-bearing capacity.

III. RESULTS AND DISCUSSION

Summary of Test Results

Property	Natural Soil	Soil + 2% Plastic	Soil + 3% Plastic	Soil + 4% Plastic
Liquid Limit (%)	42	40	38	36
Plastic Limit (%)	30	28	26	25
Plasticity Index (%)	12	12	12	11
CBR Value (%)	4.5	6.2	7.8	8.5
Water Absorption	High	Moderate	Low	Very Low
Soil Stability	Moderate	Improved	Enhanced	Highly Enhanced



Improvement in CBR Value

The most significant finding of this study is the substantial improvement in CBR value from 4.5% to 7.8%, representing a 73% increase in bearing capacity. This enhancement can be attributed to several mechanisms:

Reinforcement Effect: Plastic strips or fibres act as discrete reinforcing elements within the soil matrix, similar to the reinforcement mechanism in fibre-reinforced soils. These plastic particles create a three-dimensional network that distributes applied loads more effectively

Increased Friction: The plastic particles increase inter-particle friction within the soil mass. When load is applied, the plastic pieces resist deformation and provide additional shear resistance.

Interlocking Mechanism: The irregular shapes of shredded plastic pieces create mechanical interlocking with soil particles, enhancing the overall structural integrity of the soil-plastic composite

Reduced Moisture Sensitivity: Plastic's hydrophobic nature reduces the soil's water absorption capacity, maintaining strength even under moisture variations. This is particularly important for subgrade materials that may be exposed to seasonal moisture changes.

The 73% improvement in CBR is consistent with findings reported in recent literature, where plastic waste incorporation at optimal percentages (0.5-3%) has shown CBR improvements ranging from 50-120%.

Reduction in Plasticity

Both liquid limit and plastic limit decreased with the addition of 3% plastic waste:

Liquid limit reduced from 42% to 38% (9.5% reduction)

Plastic limit reduced from 30% to 26% (13.3% reduction)

Despite both limits decreasing, the Plasticity Index (PI = LL - PL) remained at 12%, indicating that the overall plastic range was maintained. The reduction in both limits signifies:

Reduced water absorption capacity due to hydrophobic plastic particles

Lower moisture sensitivity, meaning the soil properties are less affected by moisture variations

Improved dimensional stability with reduced shrinkage and swelling potential

Enhanced workability for construction applications

These changes are beneficial for construction purposes, particularly in regions with seasonal moisture variations or where expansive soils cause foundation problems.

Moisture Content Reduction

The observed reduction in moisture content during testing (from 25% to 21% during plastic limit test) demonstrates the water-repelling characteristics of plastic waste. This property offers several advantages:

Faster drying and curing of stabilized soil during construction

Reduced susceptibility to moisture-induced volume changes

Better performance during rainy seasons or in areas with high water table

Lower maintenance requirements for pavements and structures

Comparison

The results of this study align well with findings reported in recent research on plastic waste soil stabilization:

Azam et al. (2024) reported that plastic waste significantly improves soil stability and mitigates environmental contamination risks

Studies have shown that the optimum plastic content typically ranges from 0.5% to 3%, with maximum improvements observed at lower percentages. Beyond 3-4%, excessive plastic can reduce soil cohesion and lead to decreased performance

Research indicates that CBR improvements of 50-120% are commonly achieved with plastic waste addition, consistent with the 73% improvement observed in this study

The reduction in liquid limit and plastic limit observed in this study matches trends reported in literature, where plastic addition consistently reduces plasticity characteristics

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The hydrophobic effect of plastic particles reducing water absorption has been documented in multiple studies, confirming the moisture content reductions observed in this research

Limitations of the Study

While the results are promising, certain limitations should be acknowledged:

Limited Plastic Content Range: This study focused on 3% plastic content based on literature review. Future studies could explore a wider range of percentages (0.5%, 1%, 2%, 3%, 4%, 5%) to determine the optimal content for maximum improvement.

Single Soil Type: The study was conducted on locally available cohesive soil. Different soil types (sandy soils, silty soils, highly plastic clays) may exhibit different responses to plastic stabilization.

Plastic Type: The study used mixed plastic waste (primarily PE and PP). Research on specific plastic types might reveal variations in effectiveness.

Long-term Performance: Laboratory tests provide short-term strength characteristics. Long-term durability, degradation behavior, and performance under repeated loading cycles require further investigation.

Environmental Conditions: The study was conducted under controlled laboratory conditions. Field trials under actual construction conditions would provide more comprehensive performance data.

Soaked CBR: The CBR test was conducted on unsoaked samples. Testing soaked CBR (after 4 days of water immersion) would provide additional information about performance under saturated conditions.

IV. FUTURE SCOPE

The future scope of this study includes further improvements and additional research on soil stabilization using plastic waste. Different percentages of plastic such as 0.5% to 5% can be tested to find the exact optimum content for better results. Various types of plastic like polyethylene, PET, and PVC can also be used to check which gives the best performance. The effect of plastic size and shape can be studied, as smaller or fibrous pieces may improve strength differently. This method can be tested on different types of soil such as sandy, silty, and clayey soils. Plastic waste can also be used along with other stabilizers like lime or cement to improve soil properties further. Long-term studies and soaked CBR tests can be done to check durability and performance in wet conditions. Field tests and real construction projects can help verify the laboratory results. In addition, tests on compaction, shear strength, and permeability can be carried out for better understanding. Environmental impact and cost analysis should also be studied to ensure that this method is safe, economical, and suitable for practical use.

V. CONCLUSION

Property	Natural Soil	Soil + 3% Plastic	Observation / Improvement
Liquid Limit (%)	42	38	Decreased water absorption
Plastic Limit (%)	30	26	Reduced plasticity
Plasticity Index (%)	12	12	Nearly unchanged
CBR Value (%)	4.5	7.8	73% increase in strength
Water Absorption	High	Low	Improved durability
Soil Stability	Moderate	Enhanced	Better load-bearing capacity

This experimental investigation successfully demonstrates that plastic waste can be effectively utilized as a soil stabilizing agent, providing a sustainable solution that addresses both geotechnical engineering challenges and environmental concerns

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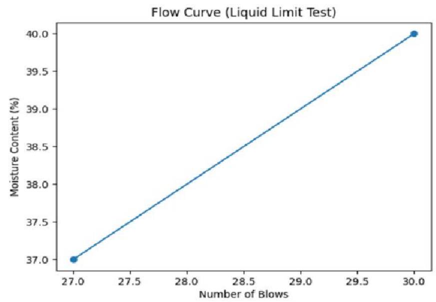

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