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NANOTECHNOLOGY IN PLASTIC WASTE UTILIZATION FOR SOIL IMPROVEMENT

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ABSTRACT: The increasing concern over plastic waste disposal and environmental sustainability has prompted the exploration of alternative applications for these non-biodegradable materials. This research focuses on the utilization of plastic waste, specifically polyethylene terephthalate (PET) and polypropylene (PP), as stabilizing agents for soil improvement in geotechnical engineering. Soil stabilization is an essential process in civil engineering, employed to enhance soil properties such as strength, load-bearing capacity, and resistance to deformation.

In this study, various percentages of plastic waste (0%, 0.5%, 1%, 1.5%, 2%, and 2.5%) were incorporated into soil samples. Experimental tests, including the Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), and Standard Proctor Tests, were conducted to evaluate the effects of plastic waste on soil stability and performance. The results demonstrate that the addition of 1.5% plastic strips yielded the highest improvement in soil properties, with an increase in both UCS and CBR values, indicating enhanced soil strength and load-bearing capacity.

This study presents a sustainable and innovative solution for both soil stabilization and plastic waste management. The findings suggest that plastic waste can be effectively used to improve the geotechnical properties of soil, making it a promising alternative to traditional stabilizers such as cement or lime. This dual benefit of waste management and construction improvement paves the way for greener, more sustainable civil engineering practices.

Keywords: Soil Stabilization, Geotechnical properties, plastic waste, soil strength, stabilization, Polyethylene Terephthalate (PET), California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS), Sustainable Construction

1. INTRODUCTION

Soil stabilization is a key practice in civil engineering, employed to improve the engineering properties of soil, which is critical for the stability and longevity of infrastructure such as roads, foundations, and embankments. Traditional methods for soil stabilization have relied on the use of chemical additives like lime and cement, or mechanical treatments such as compaction. However, these methods often come with significant environmental and economic costs, prompting the search for more sustainable and cost-effective alternatives.

One of the most pressing environmental challenges of the modern era is the disposal of plastic waste. Globally, millions of tons of plastic waste are produced annually, with a large portion ending up in landfills or natural ecosystems, where it persists due to its non-biodegradable nature. As plastic waste accumulates, it poses severe threats to wildlife, human health, and the environment. Given this backdrop, researchers and engineers have been exploring innovative ways to repurpose plastic waste, turning what is typically an environmental burden into a useful resource.

In recent years, the potential of plastic waste to enhance soil stabilization has gained increasing attention. Materials such as PET and PP, which are commonly found in plastic bottles, packaging materials, and bags, exhibit properties that can be beneficial when integrated into soil stabilization practices. These plastics, when shredded or cut into strips, can increase the cohesion, tensile strength, and load-bearing capacity of soils. Incorporating plastic waste into soil stabilization not only addresses the challenge of plastic disposal but also offers improvements in soil performance, particularly in construction applications where soil strength is paramount.

This research investigates the effectiveness of using PET and PP waste materials in varying percentages to stabilize soil. The study aims to determine the optimal plastic content that maximizes soil strength, reduces deformation, and enhances overall stability. By evaluating the Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), and other key geotechnical properties, this study provides valuable insights into the practical application of plastic waste in geotechnical engineering.

The broader implications of this research are significant: it offers a sustainable approach to two critical challenges—improving soil stability for construction purposes and reducing the environmental impact of plastic waste. As industries and governments around the world seek to adopt more eco-friendly practices, the use of plastic waste in soil stabilization presents a compelling case for integrating waste management with civil engineering innovations.

2. LITERATURE REVIEW

Agrawal (2020) explored the use of plastic waste in improving bitumen road properties. The study showed that incorporating plastic waste into road construction materials significantly improved their durability and load-bearing capacity. This research underscores the potential of using plastic waste in broader geotechnical applications, including soil stabilization.

Dhone and Agrawal (2020) explored the use of lightweight materials, including plastic waste, in the development of floating concrete. Their study demonstrated that the incorporation of plastic waste improved the structural integrity and compressive strength of the concrete. These findings suggest that plastic waste can similarly enhance the mechanical properties of soil when used in stabilization projects.

Shrivastav (2020) explored the integration of plastic waste in wastewater treatment plants, indirectly supporting the use of waste plastic in other environmental applications such as soil stabilization. Their findings further highlight the versatility of plastic waste as a material that can be repurposed in various civil engineering applications

Agrawal (2017) reviewed the solid waste management practices of Indore City, focusing on recycling strategies for plastic waste. This study highlighted the critical role of sustainable waste management solutions, including the repurposing of plastic materials for construction uses such as soil stabilization. The insights from this review are foundational for understanding the broader environmental context of using plastic in geotechnical engineering.

Patil et al. (2016) examined the reinforcement of soil using plastic bottle strips. Their research demonstrated that the addition of plastic strips improved the cohesion and shear strength of the soil by up to 67.18%, with an increase in the CBR values. This work provided early evidence of the effectiveness of plastic waste in enhancing soil mechanical properties.

Harish and Ashwini (2016) studied the effects of plastic bottle strips on the stabilization of red and black cotton soils. Their research indicated a significant improvement in soil strength when plastic was used, especially in pavement applications. The study reinforced the idea that plastic waste can be an effective stabilizer for various soil types.

Sujitkawade et al. (2016) conducted a study on the combined use of lime and geogrid for soil stabilization. While the focus was on traditional stabilizers, the research suggested that alternative materials, including plastic waste, could offer similar benefits when integrated into geotechnical engineering practices.

S.W. Thakare and S.K. Sonule (2013) conducted laboratory tests on sandy soils reinforced with plastic water bottles. Their findings showed that the inclusion of plastic waste improved the ultimate bearing capacity of the soil, demonstrating the potential of plastic waste as a soil stabilizer in geotechnical projects.

Babu and Chouksey (2011) examined the impact of plastic waste on soil compaction and shear strength. They concluded that plastic waste not only enhanced the soil's load-bearing capacity but also reduced its compressibility, supporting its use in subgrade and pavement construction.

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3. METHODOLOGY

This research study aims to investigate the effects of plastic waste on soil stabilization. The methodology consists of several key steps, including sample preparation, experimental testing, and data analysis.

1. Sample Preparation

1.1. Soil Collection:

Soil samples were collected from the Greater Noida region at a depth of 1 to 1.5 meters. The collected soil was classified based on its particle size distribution and engineering properties according to the standards specified in IS: 2720 (Part 1) - 1983.

1.2. Plastic Waste Collection:

Plastic waste materials, specifically polyethylene terephthalate (PET) bottles and polypropylene (PP) bags, were collected. These materials were cleaned, cut into smaller strips or granules, and prepared for mixing with the soil. The dimensions of the plastic strips used in the study were approximately 2 cm × 1 cm.

1.3. Mixing Proportions:

Different percentages of plastic waste were mixed with the soil to evaluate the stabilization effects. The proportions used in the study included 0% (control), 0.5%, 1%, 1.5%, 2%, and 2.5% of plastic waste by weight of dry soil.

2. Experimental Testing

The following laboratory tests were conducted to assess the geotechnical properties of the soil before and after the incorporation of plastic waste:

2.1. Standard Proctor Test:

This test was performed to determine the maximum dry density (MDD) and optimum moisture content (OMC) of the soil. The test involved compacting soil samples in a cylindrical mould under standardized conditions to identify the point at which the soil reaches its maximum density.

2.2. California Bearing Ratio (CBR) Test:

The CBR test was conducted to measure the strength and load-bearing capacity of the stabilized soil. Cylindrical specimens were prepared at MDD and OMC, and the test involved applying a load through a piston to determine the resistance of the soil sample.

2.3. Unconfined Compression Strength (UCS) Test:

The UCS test evaluated the compressive strength of the soil samples with and without plastic waste. Specimens were prepared and subjected to unconfined axial loading until failure occurred, allowing for the determination of the soil’s compressive strength.

2.4. Liquid Limit and Plastic Limit Tests:

The liquid limit (LL) and plastic limit (PL) tests were performed to determine the plasticity index (PI) of the soil. These tests assess the moisture content at which the soil changes from a plastic to a liquid state and the moisture content at which the soil changes from a semi-solid to a plastic state, respectively.

2.5. Free Swelling Index Test:

This test was conducted to measure the potential swelling characteristics of the soil. A sample of the soil was submerged in water, and the increase in volume was measured to assess the swelling potential, which is crucial for understanding soil behaviour under moisture changes.

2.6. Sieve Analysis:

Sieve analysis was performed to determine the particle size distribution of the soil. This test involved passing the soil through a series of sieves with different mesh sizes to classify the soil based on its grain size.

2.7. Specific Gravity Test:

The specific gravity of the soil was determined to evaluate the soil's density relative to the density of water. This test is important for calculating the degree of saturation and for use in other geotechnical calculations.

3. Data Analysis

The results from the laboratory tests were analysed to determine the effectiveness of plastic waste in stabilizing soil. Comparisons were made between the geotechnical properties of the untreated soil and the soil modified with various percentages of plastic waste. Statistical methods were employed to assess the significance of the findings, and graphical representations were created to visualize the impact of plastic waste on soil properties.

4. RESULTS

1. Testing of Soil Samples

The following table summarizes the results of the Unconfined Compressive Strength (UCS) and Shear Strength (SS) tests conducted on soil samples with varying percentages of plastic waste:

Plastic Waste Content (%)	Unconfined Compressive Strength (KN/m^2)	Shear Strength (KN/m^2)
0.0	16.5	14.75
0.5	23.0	15.25
1.0	25.9	16.95
1.5	31.6	18.90
2.0	30.8	18.00
2.5	28.75	16.35

2. Key Observations

- **Unconfined Compressive Strength (UCS)**: The UCS increased as the percentage of plastic waste added to the soil increased, reaching a peak at 1.5% plastic content (31.6 KN/m^2). Beyond this point, the UCS began to decline with higher percentages of plastic waste.
- **Shear Strength (SS)**: Similar to the UCS, the shear strength also exhibited a positive trend with increasing plastic content, peaking at 1.5% (18.90 KN/m^2). At higher plastic percentages, the shear strength showed a slight decrease.

5. CONCLUSION

This study aimed to investigate the potential of plastic waste materials, specifically polyethylene terephthalate (PET) and polypropylene (PP), as effective stabilizers for soil. The research focused on the incorporation of varying percentages of plastic waste (0%, 0.5%, 1%, 1.5%, 2%, and 2.5%) into soil samples and evaluated their effects on key geotechnical properties, including Unconfined Compressive Strength (UCS) and Shear Strength (SS).

The experimental findings revealed several important insights:

1. **Improvement in Soil Strength**: The incorporation of plastic waste significantly enhanced the engineering properties of the soil. The UCS and shear strength of the soil increased with the addition of plastic waste, reaching optimal values at 1.5% plastic content. The maximum UCS observed was 31.6 KN/m^2, while the peak shear strength was 18.90 KN/m^2. This demonstrates the effectiveness of plastic waste in improving the load-bearing capacity and stability of soil, making it a viable alternative to traditional soil stabilizers like lime and cement.
2. **Optimal Plastic Content**: The results indicated that 1.5% was the optimal percentage of plastic waste for soil stabilization. Beyond this concentration, the strength values began to decline, suggesting that there is a threshold beyond which additional plastic waste may negatively affect soil performance. This finding is crucial for practical applications, as it provides clear guidelines for the effective use of plastic waste in construction projects.

3. **Sustainability Implications**: The use of plastic waste in soil stabilization offers a sustainable solution to two pressing challenges: improving soil properties for construction and managing plastic waste effectively. Given the significant environmental issues associated with plastic disposal, repurposing these materials for geotechnical applications contributes to waste reduction and promotes eco-friendly construction practices. This aligns with global efforts towards sustainable development and waste management.

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