A REVIEW ON – SOIL STABILIZATION USING WASTE PLASTIC MATERIALS

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***Abstract*—**Plastic waste has emerged as one of the most critical environmental challenges of the modern era, with millions of tons generated annually worldwide. Most plastics are non-biodegradable, persisting in the environment for hundreds of years and causing ecological and health hazards. At the same time, the civil engineering sector continues to face challenges in stabilizing weak soils, particularly expansive clays and black cotton soils, which pose difficulties for infrastructure development due to their low strength and high swelling potential. Researchers have recently proposed the use of waste plastics as soil stabilizers, offering a sustainable solution that addresses both waste management and geotechnical problems. This review paper consolidates findings from multiple experimental studies on the use of polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), Plastic fibers, Plastic bottles and plastic covers in soil stabilization. The review discusses methods of plastic incorporation, laboratory test outcomes, and improvements in engineering properties, environmental benefits, and challenges. The results highlight that waste plastics can substantially enhance strength parameters such as unconfined compressive strength (UCS) and California Bearing Ratio (CBR), reduce swelling behavior, and provide a cost-effective alternative to conventional stabilizers like cement and lime. However, the technique requires further field-scale research and standardization before large-scale application.

Index Terms— Soil stabilization, Plastic waste, Polyethylene terephthalate (PET), Expansive soil, Plastic fibre, California Bearing Ratio (CBR), Sustainable construction.

I. INTRODUCTION

Plastic consumption has increased rapidly over the last few decades due to its versatility, durability, and low cost. Unfortunately, the same properties make plastic a major pollutant once discarded, as it does not degrade easily. In countries with high urban populations, the accumulation of plastic waste creates significant disposal issues, filling landfills, clogging drainage systems, and polluting soil and water bodies. According to recent estimates, billions of plastic items are discarded daily, and only a fraction of them are recycled effectively.

Simultaneously, the construction industry faces recurring challenges in dealing with problematic soils. Expansive clays, silty soils, and black cotton soils are widely distributed in many parts of Asia and Africa and are known for their high compressibility, poor load-bearing capacity, and significant volume changes under moisture variation. Such soils threaten the stability of pavements, foundations, slopes, and embankments. Traditional stabilization techniques rely on cement, lime, or fly ash. While effective, these methods are expensive, energy-intensive, and environmentally harmful due to carbon emissions associated with cement and lime production.

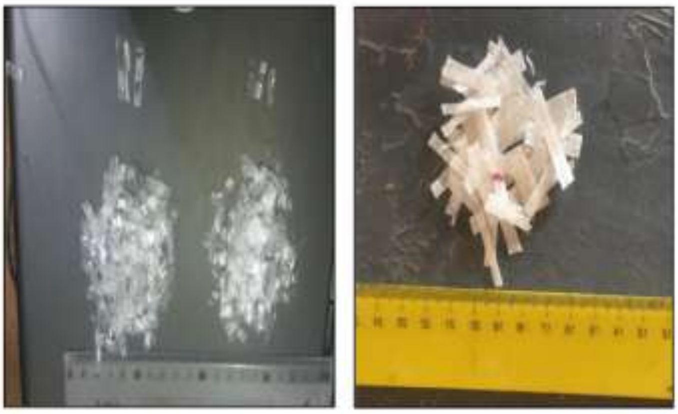

Figure 1- Sample of Plastic Waste Fibres (Hussein Jalal Aswad Hassan et al 2021)

Types of Waste Plastics Used in Soil Stabilization-

Different forms of plastics have been tested to evaluate their effectiveness as soil stabilizers:

1. **Polyethylene (PE) and Polypropylene (PP):** These plastics, commonly used in bottles, bags, and packaging, have been cut into short fibres (typically 10–20 mm). Studies indicate significant improvement in strength and CBR when used at low percentages (1–4% of soil weight).
2. **Polyethylene Terephthalate (PET):** Derived from water and soft drink bottles, PET has been shredded or cut into strips for stabilization of expansive soils. Research on black cotton soils revealed improved shear strength and reduced swelling potential when PET waste was introduced.
3. **Plastic Covers and Bags:** Thin polythene covers have been cut into strips and randomly mixed with soil. These reinforcements mimic fibre-reinforced soil behaviour, improving tensile resistance and stability.
4. **Mixed Plastic Waste:** Some experimental programs tested combinations of different plastic wastes such as LDPE, HDPE, and PET strips. These trials demonstrated that even unsorted plastic wastes could yield measurable geotechnical benefits.
5. **Plastic Fibre:** Plastic fibres are good for soil stabilization as they improve strength, compaction, and durability while reducing shrinkage and cracks. They provide a cost-effective, eco-friendly solution by reusing plastic waste, making soil more suitable for roads, embankments, and foundations.

By recycling such materials into soil stabilization projects, plastic waste is not only diverted from the environment but also converted into a valuable construction resource. The reuse of waste plastic materials in soil stabilization presents a promising alternative. By introducing plastic strips or fibres into the soil, researchers aim to improve shear strength, bearing capacity, and durability, while simultaneously reducing environmental waste. Several experimental investigations over the past decade have evaluated different plastic types, fibre geometries, and mixing ratios, yielding encouraging results. This paper reviews these studies in detail to assess the potential and limitations of plastic-based soil stabilization.

II. Relevance

This study is relevant as it provides a sustainable and economical method of soil stabilization by reusing waste plastic fibres. It not only improves soil strength and stability but also helps in reducing environmental problems caused by plastic waste. This study is relevant as it explores an eco-friendly way of stabilizing soil using polyethylene waste materials with binders. It helps improve soil strength and durability while simultaneously addressing the issue of plastic waste management, offering a sustainable and cost-effective solution for construction applications. This approach not only provides a cost-efficient method for soil stabilization but also offers an eco-friendly solution to manage non-biodegradable plastic waste.

III. Objective

- To provide a sustainable solution for plastic waste management while enhancing soil performance for construction and geotechnical applications.
- To analyse the effect of including waste plastic fibres in soil and evaluate their role in improving soil stability in a cost-effective manner.
- To test different percentages of plastic fibre replacement (0.25%, 0.5%, 1%, and 1.5%) and assess their influence on properties like maximum dry density and compressive strength.
- To evaluate the effectiveness of polyethylene waste materials combined with binders, in enhancing soil strength and stability for construction applications.
- To provide a sustainable and eco-friendly alternative for soil stabilization while addressing the issue of plastic waste management.
- To investigate the potential of waste plastic materials in improving the engineering properties of soil for construction purposes.
- To promote sustainable waste management by utilizing non-biodegradable plastic in soil stabilization

IV. Scope of Review

The scope of this study is to explore the use of waste plastic in soil stabilization to improve soil performance while promoting sustainable waste management in construction applications. To improve soil strength and stability using waste plastic fibres, offering a cost-effective and eco-friendly solution for construction. It also helps in managing plastic waste by converting it into a useful material for ground improvement. To enhance soil strength using polyethylene waste with binders while promoting a sustainable solution for plastic waste management. To improve black cotton soil strength using waste PET bottles while promoting eco-friendly plastic waste management.

V. Literature Review

Kirubakaran. K et al (2016): Research has shown that plastic waste can effectively stabilize weak soils. Ashraf & Sunil (2013) found that plastic strips improved soil shear strength, while Poweth et al. (2014) reported that plastic granules enhanced density and compressive strength. Similarly, Damion et al. (2016) demonstrated that PET bottle strips improved subgrade strength for pavements. Overall, studies agree that adding a small percentage of plastic waste (3–7%) significantly improves soil properties, offering a low-cost and eco-friendly solution for soil stabilization.

S. Peddaiah et al (2016): examined the stabilization of clayey soils using waste plastic fibres cut from discarded milk and curd packets. Their study focused on silty clay soils, which are known for high shrink–swell potential and poor load-bearing capacity. The authors tested different replacement levels of soil with plastic fibres (0.25%, 0.5%, 1%, and 1.5%) using Standard Proctor and Unconfined Compressive Strength (UCS) tests. Results showed that the optimum improvement occurred at 0.5% plastic content, where maximum dry density increased and UCS nearly doubled compared to untreated soil. Beyond this percentage, both compaction and strength values declined, indicating that excess plastic reduces soil cohesion. The findings align with earlier studies on fibre reinforcement, confirming that plastic fibres can improve compaction, cohesion, and load-carrying capacity of weak soils when used in small amounts. The study also emphasized the environmental benefits of utilizing non-degradable plastic waste in soil stabilization, turning an environmental burden into a useful construction material.

Jasmin Varghese Kalliyath et al (2016): investigated the stabilization of clayey soil using waste plastic fibres cut from discarded milk and curd packets. Their study focused on silty clay, a soil type known for its high compressibility, swelling, and shrinkage problems. Plastic fibres were mixed with soil at varying percentages (0.25%, 0.5%, 1%, and 1.5%), and laboratory tests such as Standard Proctor and Unconfined Compressive Strength (UCS) were conducted. The results showed that adding 0.5% plastic fibres produced the best improvements, with maximum dry density increasing from 1.29 g/cm³ to 1.38 g/cm³, while UCS nearly doubled compared to untreated soil. Beyond this percentage, strength values began to decline due to reduced soil cohesion and poor bonding. The study concluded that waste plastic fibres can significantly enhance soil properties at low dosages, providing better compaction, strength, and resistance to shrink–swell behaviour. Moreover, it emphasized the dual advantage of waste management and cost-effective soil improvement, demonstrating that plastic waste can be transformed from an environmental problem into a valuable engineering resource

Nicoleta-Maria Ilies et al (2016): has highlighted the effectiveness of waste plastics as soil stabilizers. Studies have shown that shredded polyethylene and other plastic wastes can improve compaction properties and increase bearing capacity when mixed with soil. Researchers also noted that combining plastic waste with traditional binders such as cement or lime provides even greater improvement in unconfined compressive strength (UCS) and California Bearing Ratio (CBR) values. Overall, the literature agrees that waste polyethylene can be a sustainable alternative for soil stabilization, especially when used in combination with binders for road and foundation applications.

Rebecca Belay Kassa et al (2020): Past studies have shown that expansive soils, which undergo severe swelling and shrinkage, can be improved using both traditional stabilizers (lime, cement, bitumen) and alternative waste materials. Researchers such as Seco et al. (2011) emphasized the effectiveness of chemical stabilization, while Fauzi et al. (2016) demonstrated that incorporating waste plastic and glass enhanced soil engineering properties. Similarly, Akçaözoğlu et al. (2010) reported that shredded PET bottles could successfully be reused in construction materials, highlighting their strength and sustainability benefits. Overall, the literature indicates that waste plastics not only enhance soil strength, compaction, and durability, but also offer a low-cost, eco-friendly solution to soil stabilization while addressing plastic waste management challenges.

Hussein Jalal Aswad Hassan et al (2021): examined the effects of plastic waste materials on the geotechnical properties of clayey soils. The study focused on incorporating polyethylene (PE) and polypropylene (PP) fibres into soil at varying percentages (0.25–4%) and testing parameters such as Atterberg limits, compaction, unconfined compressive strength (UCS), California Bearing Ratio (CBR), and shear strength.The results showed that the inclusion of plastic fibres reduced the plasticity index, making the soil less susceptible to volume changes. Compaction tests revealed a slight reduction in maximum dry density due to the lightweight nature of plastics. However, UCS and CBR values increased significantly, with optimal performance at around 1–2% fibre content. Shear strength parameters, including cohesion and angle of internal friction, also improved, and confirming that the fibres provided reinforcement by interlocking with soil particles. The authors concluded that using waste plastic fibres in clayey soils can enhance strength, bearing capacity, and durability, making them suitable for road construction and other geotechnical applications. Additionally, they highlighted the environmental benefit of recycling plastic waste into soil stabilization projects, addressing both waste management and infrastructure challenges.

VI. RESULT AND DISCUSSION-

To examine the strength and mechanical properties of both native and stabilised soils, different laboratory tests were conducted including the determination of index properties of unstabilised soil and standard proctor compaction, UCS, CBR (soaked), and Modulus of Resilience for stabilised and unstabilised soils.

1. Effect of Plastic Waste on MDD & OMC-

The studies show that the inclusion of plastic waste in soil has a clear effect on both Maximum Dry Density (MDD) and Optimum Moisture Content (OMC). When plastic waste is mixed with soil, the MDD generally decreases because plastic is lightweight and less dense compared to soil particles. This reduction in density occurs as the plastic content increases, leading to lower compacted unit weight. On the other hand, the OMC tends to increase with the addition of plastic waste. This is attributed to the fact that plastic particles reduce the effective contact between soil grains, requiring more moisture to achieve the desired lubrication and compaction effect. In summary, the addition of plastic waste decreases the maximum dry density of soil while increasing its optimum moisture content, with the extent of change depending on the proportion and type of plastic waste used.

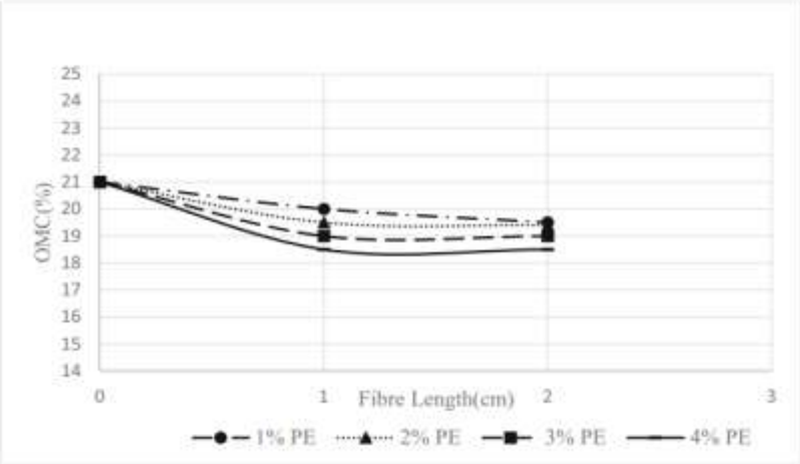

Figure 2 –Effect of PE ratio on OMC (Hussein Jalal Aswad Hassan et al 2021)

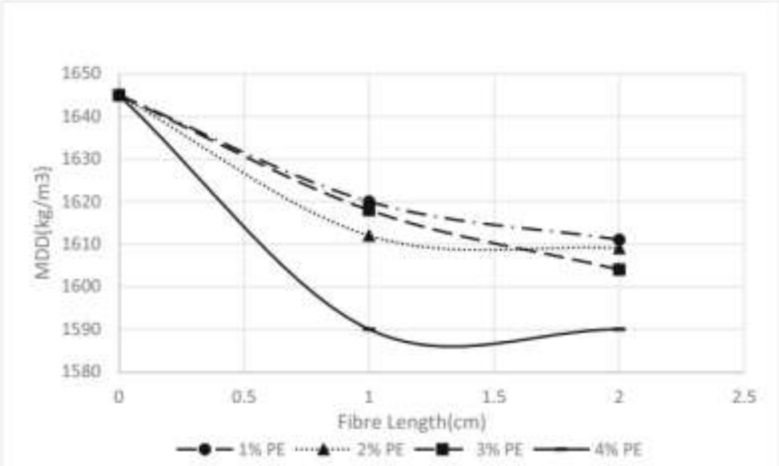

Figure 3 –Effect of PE ratio on MDD (Hussein Jalal Aswad Hassan et al 2021)

2. Effect of Plastic Waste on Shear Strength Parameters –

Using waste plastic in soil tends to improve its shear strength mainly through an increase in cohesion, while the change in the angle of internal friction is usually minor. The fibres act as reinforcement within the soil mass, creating additional bonding and restricting particle movement, which results in higher cohesion values. This improvement is most effective at lower fibre contents (around 1–2%) and with longer fibre pieces that provide better interaction with the soil. The angle of internal friction may show a slight rise, but the effect is not as significant as that on cohesion since the fibres primarily contribute tensile resistance rather than altering grain-to-grain friction. When used together with stabilizing agents such as lime or cement, both cohesion and friction angle show greater improvement, as the binders reduce soil plasticity and promote stronger particle interlock. In summary, waste plastic enhances soil shear strength largely by strengthening cohesion, while its influence on friction angle remains comparatively limited.

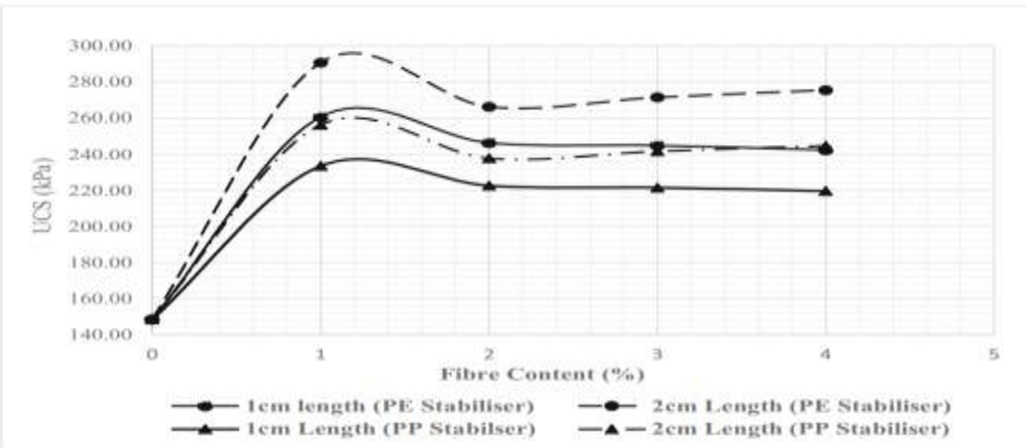

Figure 4 UCS test results for PE and PP with 1-cm and 2-cm lengths at different fibre contents(Hussein Jalal Aswad Hassan et al 2021)

3. **Effect of Plastic Waste on CBR Values –**
   The addition of waste plastic to soil has a clear positive effect on its California Bearing Ratio (CBR), which reflects the load-bearing capacity and deformation resistance of subgrade soils. Test results show that incorporating polyethylene (PE) and polypropylene (PP) fibres into clayey soils leads to a significant increase in CBR compared to untreated soil. The native soil had a CBR of about 4%, which increased by more than 55–80% with the inclusion of PE fibres and by about 42–50% with PP fibres, with longer fibres (2 cm) giving higher improvements than shorter ones. The improvement is attributed to the interaction between fibres and soil particles, where the fibres provide additional resistance to penetration and distribute loads more effectively. The increase in CBR becomes more pronounced with higher fibre contents, particularly around 3–4%, which was found to be the optimum range for maximum gain. Overall, the presence of plastic waste enhances the strength and stiffness of the soil, making it more suitable for pavement and embankment applications.

4. **Effect of Plastic Waste on Resilient Modulus –**
   The inclusion of waste plastic in soil has been shown to influence the modulus of resilience significantly. When polyethylene (PE) and polypropylene (PP) waste plastics are cut into fibre form and mixed with clayey soils, the resilient modulus generally improves due to enhanced interlocking between soil particles and fibres. Studies report that the modulus of resilience can increase by as much as 120% with 4% PE fibre content, while PP fibres show improvement up to an optimum level of around 2–3% before the benefits begin to decline. This improvement occurs because the fibres provide additional tensile resistance and reduce strain under repeated loading, which strengthens the soil's capacity to withstand deformation under traffic or cyclic stresses. Overall, the effect of waste plastic fibres is positive, but the performance depends on both the type of plastic and the dosage used; excessive amounts may lead to reduced efficiency due to slippage or poor bonding within the soil matrix.

VII. CONCLUSION-

1. Optimum Plastic Content (0.5%) improves soil properties. The inclusion of 0.5% waste plastic fibres in clayey soil significantly reduces Optimum Moisture Content (OMC) and increases both Maximum Dry Density (MDD) and Unconfined Compressive Strength (UCS). This dosage was found to be the most effective, making the soil more stable and suitable for engineering applications.
2. Sustainable and Economical Solution using waste plastic fibres for soil stabilization not only improves soil strength but also provides a low-cost, eco-friendly method of reusing plastic waste, effectively addressing environmental disposal problems while enhancing geotechnical performance.
3. Polyethylene waste enhances soil strength and compaction properties the study found that adding shredded polyethylene waste to soil improved its Maximum Dry Density (MDD) and California Bearing Ratio (CBR) values, while also reducing the plasticity index. This shows that plastic waste can effectively stabilize weak soils.
4. Best results achieved with polyethylene + binder combination while polyethylene alone improved soil stability, the combination with cement or lime produced the highest strength gains in both Unconfined Compressive Strength (UCS) and CBR tests, making it more suitable for pavements and foundation applications.
5. Plastic waste effectively improves soil properties – Small dosages of plastic waste (around 0.5– 1.5%) enhance compaction, increase strength (CBR and UCS), and reduce plasticity of soils.
6. Eco-friendly stabilization method – Using plastic waste for soil stabilization not only strengthens weak soils but also provides a sustainable solution for plastic waste management.
7. Adding 5% PET bottle waste significantly improves the strength, compaction, and CBR values of black cotton soil, making it suitable for foundation and pavement applications.
8. Using PET waste for soil stabilization is both cost-effective and eco-friendly, offering a sustainable method for plastic waste management while enhancing soil performance.
9. The combined use of plastic waste improves the compaction, strength, and CBR values of weak soils, making them more suitable for construction purposes.

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