

Plastic Waste Management Practices

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ABSTRACT: Plastic waste management has emerged as a critical global challenge due to the rapid increase in plastic consumption and its non-biodegradable nature, leading to severe environmental, economic, and social impacts. This study focuses on sustainable plastic waste management practices with particular emphasis on the utilization of Low-Density Polyethylene (LDPE) waste in geotechnical applications for soil stabilization. The research integrates circular economy principles with engineering practices by converting waste plastic into a value-added construction material. Experimental investigations were conducted on black cotton soil mixed with varying plastic contents of 1%, 2%, and 3% to evaluate changes in engineering properties. The results indicate that the inclusion of plastic waste significantly improves soil performance, with the California Bearing Ratio (CBR) increasing from 2.63% to 6.3% and Unconfined Compressive Strength (UCS) rising from 0.550 kg/cm² to 0.662 kg/cm² at optimum plastic content. Additionally, the Free Swell Index reduced from 63.33% to 33%, demonstrating enhanced soil stability and reduced expansion characteristics. The study also highlights environmental benefits such as reduced landfill accumulation, lower greenhouse gas emissions, and conservation of natural construction materials. Furthermore, global literature emphasizes the need for integrated waste management strategies, technological innovations, and policy reforms to address plastic pollution effectively. Overall, the research demonstrates that plastic waste utilization in soil stabilization offers a sustainable, cost-effective, and environmentally responsible solution for infrastructure development.

Keywords: *Plastic Waste Management, Soil Stabilization, LDPE, Circular Economy, Black Cotton Soil, CBR, UCS, Sustainable Construction*

I. INTRODUCTION

Plastic waste management has become one of the most pressing challenges of the modern era, especially due to the widespread use of plastics in almost every sector of life. While plastics offer significant benefits in terms of cost, durability, and convenience, their environmental impact is undeniable. Plastic waste poses severe risks to ecosystems, wildlife, and human health, primarily because of its non-biodegradable nature and tendency to accumulate in the environment. As plastic production continues to rise globally, so does the volume of plastic waste generated, leading to an urgent need for effective and sustainable management practices. The complexity of managing plastic waste stems from its variety in forms, ranging from packaging to household goods, electronics, and automotive parts. With the increasing realization of its environmental impact, the global community has started focusing on reducing plastic waste generation, enhancing recycling efforts, and promoting sustainable

consumption patterns. The importance of plastic waste management has grown so significantly that it has been integrated into global policy frameworks, such as the United Nations' Sustainable Development Goals (SDGs), emphasizing the need for circular economy approaches.

Managing plastic waste is an ongoing challenge, especially because of the complex nature of plastics and their high consumption rates in daily life. One of the primary difficulties is the sheer volume of plastic waste generated, which overwhelms existing waste management systems in many parts of the world. Plastics come in various types, each with different chemical properties, and not all are recyclable. This diversity complicates the sorting process, making it difficult to recover valuable materials from mixed waste. Even with established recycling technologies, the contamination of plastic waste with food residues, chemicals, and other waste materials reduces its recyclability and increases processing costs. Moreover, inadequate waste

management infrastructure in developing countries exacerbates the situation. Poorly designed waste collection and sorting systems, coupled with insufficient investment in recycling facilities, lead to large amounts of plastic waste being either improperly disposed of in landfills or incinerated. The environmental consequences of these methods are far-reaching, contributing to air pollution, soil contamination, and oceanic plastic accumulation. The lack of global consistency in waste management practices further complicates the issue, as various countries and regions adopt different approaches based on local resources, economic priorities, and political will.

To address the mounting plastic waste crisis, a variety of strategies have been developed and are being implemented worldwide. Waste reduction at the source is one of the most effective approaches to curbing plastic waste generation. This can be achieved by promoting the use of reusable packaging, reducing single-use plastics, and encouraging product designs that facilitate recycling. Many countries have adopted policies banning or restricting single-use plastic items, such as plastic bags, straws, and cutlery. Such measures have proven effective in reducing plastic waste, as seen in regions like Europe, where plastic bag usage has decreased significantly due to these legislative actions. Another crucial strategy for managing plastic waste is recycling, particularly mechanical recycling, which involves collecting, sorting, and processing used plastics into new products. Mechanical recycling is a widely used and established method for plastics such as PET and HDPE, which are commonly found in packaging and containers. However, the recycling rate for plastics globally remains low, primarily due to inefficient sorting systems, a lack of awareness among consumers, and economic barriers. Expanding recycling infrastructure, improving collection systems, and creating financial incentives for recycling can help boost recycling rates significantly. Moreover, advancements in technologies such as chemical recycling, which breaks down plastics into their basic components for reuse, hold promise in addressing the limitations of mechanical recycling.

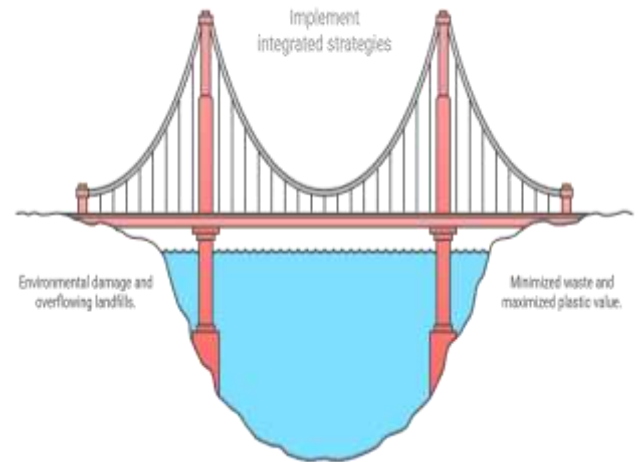


Fig 1. Effective plastic waste management transition to a circular economy

Plastic waste management practices differ across countries, depending on regional priorities, economic status, and infrastructure development. In developed countries, efficient recycling systems and technologies are more widespread. Nations like Germany, Sweden, and Japan have implemented sophisticated waste management practices, achieving high plastic recycling rates of over 60%. These countries have well-established systems for waste segregation, collection, and processing, supported by strong policies and public awareness campaigns. In contrast, developing countries face greater challenges in managing plastic waste due to the lack of infrastructure, limited technological advancements, and low recycling rates. For example, in many parts of Africa and Asia, waste is poorly segregated, and plastic waste is often dumped into rivers, oceans, or landfills. However, some developing nations have begun to take steps towards better waste management by introducing policies that promote recycling, waste-to-energy technologies, and plastic waste reduction. India, for instance, has launched the Swachh Bharat Abhiyan (Clean India Mission), which aims to enhance waste management practices across the country, including improving plastic waste recycling and awareness. In Southeast Asia, countries like Thailand and Indonesia are implementing plastic waste reduction strategies, such as plastic bag bans and promoting recycling initiatives, with the goal of reducing plastic pollution in their environments.

Plastic waste management is a multifaceted issue that requires a combination of strategies to address effectively. From waste reduction at the source to advancing recycling technologies and implementing policies that promote the circular economy, the path forward lies in comprehensive, integrated solutions.

Countries need to invest in developing better waste management infrastructures, including systems for plastic waste segregation, collection, and recycling. Additionally, fostering public awareness and behavior change, particularly in relation to reducing single-use plastics and encouraging proper recycling practices, is essential for long-term success. The adoption of advanced technologies, such as chemical recycling, presents a promising avenue for addressing the challenges posed by hard-to-recycle plastics. Governments, industries, and consumers must work together to create a more sustainable plastic waste management system that minimizes environmental impact and maximizes the value of plastic materials. The global effort towards a circular economy, where plastics are reused, recycled, and reintegrated into the production cycle, holds the key to mitigating the environmental impacts of plastic waste. By tackling the plastic waste crisis through innovative solutions, regulatory frameworks, and public participation, societies can move towards a more sustainable future with reduced reliance on plastic and minimized waste generation.

II. LITERATURE REVIEW

The global challenge of plastic waste management has been extensively examined across multiple geographical and socio-economic contexts, highlighting critical environmental, legal, and technological gaps. Lais R. Lima et.al (2022) emphasized that countries like Brazil face severe plastic waste management issues due to increased consumption during the COVID-19 pandemic, particularly from protective materials, which significantly aggravated environmental pollution and exposed the vulnerabilities of informal waste pickers lacking social protection. Similarly, Hanim Kamaruddin et.al (2022) analyzed marine plastic pollution in Indonesia and Malaysia and identified weak legal enforcement, lack of specific regulatory provisions, and reliance on soft-law mechanisms as major barriers to effective waste control. Their study strongly recommended the development of stricter legal frameworks and bilateral agreements to address transboundary marine debris. Joana C. Prata et.al (2021) provided a European perspective, highlighting that Portugal generates approximately 414,000 tons of plastic packaging waste, with only 34% recycling efficiency, far below the EU target of 42%. The study further indicated that beach litter levels (330 items per 100 meters) significantly exceed acceptable limits, necessitating integrative circular economy strategies, including pyrolysis and gasification technologies. Additionally, Kerstin Kuchta et.al (2022) discussed the growing

importance of bio-based plastics, projecting an increase from 2.417 million tonnes in 2021 to 7.593 million tonnes by 2026, but also pointed out the lack of standardized waste management infrastructure and regulatory support for their disposal. These studies collectively demonstrate that despite global awareness, plastic waste management systems remain fragmented, requiring policy strengthening, technological advancement, and institutional coordination.

From a technological and sustainability perspective, recent studies have focused on innovative models and circular economy approaches to mitigate plastic pollution. Afonso D. Machecha et.al (2024) argued that banning plastics is not a practical solution due to their extensive industrial applications; instead, emphasis should be placed on reducing and reusing plastics, alongside scientific research on microplastics and their environmental impacts. Mahtab Mousavi et.al (2024) highlighted the limitations of current disposal methods such as pyrolysis due to high costs and environmental risks, advocating for biodegradable plastics and lifecycle-based waste management policies to enhance sustainability. Islam M. Rafizul et.al (2024) introduced an agent-based system dynamics model for municipal plastic waste management in Bangladesh, predicting a rise in per capita waste generation from 8.92 kg in 2023 to 11.6 kg by 2040 under baseline conditions, while policy interventions could significantly reduce waste footprint indices and riverine discharge. Similarly, Shaivya Anand et.al (2026) developed a predictive model for riverine plastic waste in the Ganga River, demonstrating that improved waste management strategies could reduce mismanaged plastic waste by 81% and river pollution by 75% by 2061. Vongdala Noudeng et.al (2024) further compared waste management practices in developing countries like Laos with advanced nations, revealing technological and infrastructural deficiencies leading to increased waste generation from 0.21 to 0.37 million tons between 2012 and 2021. Finally, Ekaterina Todorova et.al (2025) compared plastic waste systems in Kazakhstan and Bulgaria, identifying disparities in technological adoption and recommending mechanical optimization and thermochemical recycling solutions. Collectively, these studies highlight that effective plastic waste management requires an integrated approach combining policy reforms, advanced technologies, circular economy principles, and international cooperation to achieve long-term environmental sustainability.

III. RESEARCH METHOD

Plastic waste has emerged as one of the most pressing environmental challenges in the modern era due to its non-biodegradable nature and excessive consumption across industries and households. Materials such as Low-Density Polyethylene (LDPE), widely used in packaging applications like milk pouches and carry bags, contribute significantly to municipal solid waste streams. Improper disposal of these materials leads to soil contamination, water pollution, drainage blockage, and ecological imbalance.



Fig 2. Research Method

As plastics persist in the environment for hundreds of years, their accumulation has become a global concern requiring urgent intervention. Lais R. Lima et.al (2022) highlighted that the COVID-19 pandemic significantly increased plastic consumption due to protective equipment usage, further intensifying waste management challenges, especially in countries like Brazil. The study also emphasized the socio-economic issues associated with informal waste pickers who lack proper recognition and protection.

Similarly, Hanim Kamaruddin et.al (2022) pointed out that marine plastic debris has become a severe issue in Southeast Asia, particularly in Indonesia and Malaysia, due to ineffective waste management systems and weak legal frameworks. The absence of strict enforcement mechanisms and reliance on soft-law instruments has hindered the effective control of plastic pollution. These findings clearly indicate that plastic waste is not only an environmental issue but also a socio-economic and governance challenge that requires integrated policy interventions and international cooperation.

3.1 Circular Economy and Sustainable Waste Management Approaches

The concept of a circular economy has gained significant attention as a sustainable solution to plastic waste management. Instead of disposing plastic waste in landfills, it focuses on reducing, reusing, and recycling materials to minimize environmental impact. Afonso D. Macheca et.al (2024) argued that banning plastics is not a feasible solution due to their extensive industrial applications. Instead, the focus should be on minimizing plastic waste generation and enhancing reuse strategies. The study emphasized the importance of scientific advancements and global cooperation in addressing microplastic pollution and its environmental impacts.

Joana C. Prata et.al (2021) provided insights into plastic waste management in Portugal, where approximately 414,000 tons of plastic packaging waste are generated annually, with only 34% being recycled. The study highlighted that beach litter levels are significantly higher than European Union standards, indicating the need for improved waste management practices. Technologies such as pyrolysis and gasification were suggested as potential solutions for converting plastic waste into valuable products like hydrogen, thereby supporting circular economy goals. Additionally, Kerstin Kuchta et.al (2022) emphasized the growing importance of bio-based plastics, projecting a significant increase in production but also highlighting challenges related to waste segregation and lack of regulatory frameworks for their disposal.

3.2 Technological Innovations in Plastic Waste Management

Technological advancements play a crucial role in improving plastic waste management systems. Traditional disposal methods such as landfilling and incineration have significant environmental drawbacks, including greenhouse gas emissions and toxic residue

generation. Mahtab Mousavi et.al (2024) discussed the limitations of pyrolysis and highlighted that although it is a promising method, it is expensive and produces harmful by-products. The study recommended the use of biodegradable plastics and lifecycle-based waste management strategies as more sustainable alternatives.

Islam M. Rafizul et.al (2024) introduced an agent-based system dynamics model to analyze municipal plastic waste management in Bangladesh. The model predicted an increase in per capita plastic waste generation from 8.92 kg in 2023 to 11.6 kg by 2040 under baseline conditions. However, with policy interventions such as increased recycling and waste separation, the plastic waste footprint could be significantly reduced. Similarly, Shaivya Anand et.al (2026) developed a predictive model for the Ganga River basin, demonstrating that improved waste management strategies could reduce mismanaged plastic waste by up to 81% and river pollution by 75% by 2061. These findings highlight the importance of integrating advanced modeling techniques and policy measures to achieve sustainable waste management outcomes.

3.3 Comparative Analysis of Global Waste Management Practices

Plastic waste management practices vary significantly across countries due to differences in socio-economic conditions, infrastructure, and policy frameworks. compared waste management systems in developing countries like Laos with advanced nations such as Japan and Singapore. The study found that waste generation in Laos increased from 0.21 million tons in 2012 to 0.37 million tons in 2021 due to inadequate treatment facilities and reliance on unsanitary landfilling. In contrast, developed countries have successfully reduced waste generation through advanced recycling technologies and effective policy implementation.

Conducted a comparative study between Kazakhstan and Bulgaria, revealing that despite similar socio-economic conditions, their waste management practices differ significantly. The study suggested that technological advancements such as thermochemical recycling and improved mechanical waste collection systems could enhance plastic waste management efficiency. These comparative analyses highlight the importance of adopting region-specific strategies while learning from successful international practices.

3.4 Utilization of Plastic Waste in Geotechnical Engineering

In addition to waste management strategies, innovative reuse approaches such as incorporating plastic waste into construction materials have gained attention. The present study focuses on the use of LDPE plastic waste for soil stabilization, particularly in expansive soils like black cotton soil. Black cotton soil is known for its high swelling and shrinkage properties due to the presence of montmorillonite clay minerals, making it unsuitable for construction without stabilization. By mixing shredded plastic waste in proportions of 1%, 2%, and 3%, the study evaluates improvements in soil properties such as compaction, strength, and load-bearing capacity.

The methodology involves collecting plastic waste from local sources, cleaning, drying, and shredding it into small particles before mixing with soil samples. Laboratory tests such as sieve analysis, Atterberg limits, modified Proctor compaction, unconfined compressive strength (UCS), and California Bearing Ratio (CBR) tests are conducted to assess the effectiveness of plastic stabilization. The results indicate that plastic waste acts as a reinforcing material within the soil matrix, improving its structural performance and reducing deformation. This approach not only enhances soil properties but also provides an environmentally sustainable solution for plastic waste utilization.

3.5 Environmental Benefits and Sustainability Implications

The integration of plastic waste into soil stabilization offers multiple environmental benefits. It reduces the accumulation of plastic waste in landfills and open dumping sites, minimizes environmental pollution, and decreases the demand for natural construction materials. By adopting such sustainable practices, the construction industry can contribute to environmental conservation and resource efficiency. The concept aligns with global sustainability goals and promotes the development of eco-friendly infrastructure.

Furthermore, the reuse of plastic waste in engineering applications supports circular economy principles by converting waste into valuable resources. It also reduces greenhouse gas emissions associated with traditional waste disposal methods and enhances the overall sustainability of construction practices. These benefits highlight the potential of integrating environmental management with engineering solutions to address global plastic waste challenges effectively.

IV RESULTS AND DISCUSSION

This chapter presents the results obtained from the laboratory experiments conducted to evaluate the effectiveness of plastic waste in soil stabilization and its influence on the engineering properties of soil. The study focuses on the use of shredded LDPE plastic waste mixed with soil in different proportions of 1%, 2%, and 3% by weight of dry soil. The soil samples were prepared and tested under controlled laboratory conditions to analyze their physical and mechanical properties. Various standard geotechnical tests such as the compaction test, Atterberg limits test, Unconfined Compressive Strength (UCS) test, Free Swell Index test, and California Bearing Ratio (CBR) test were performed. These tests help in understanding the behavior of soil when plastic waste is incorporated and determine whether the addition of plastic improves the strength and stability of the soil for construction purposes.

The results obtained from these tests were carefully analyzed and compared with the properties of untreated soil to evaluate the effectiveness of plastic waste as a soil stabilizing material. The CBR test results were interpreted using standard penetration loads at different penetration levels such as 2.5 mm, 5 mm, 7.5 mm, 10 mm, and 12.5 mm. The analysis focuses on identifying the optimum percentage of plastic waste that provides improved soil strength, better load-bearing capacity, and reduced swelling behavior. The discussion also examines the environmental significance of utilizing plastic waste in soil stabilization, as it helps reduce plastic pollution and promotes sustainable waste management practices. Overall, this chapter provides a detailed interpretation of the experimental findings and highlights the potential of plastic waste as an eco-friendly material for geotechnical engineering applications.

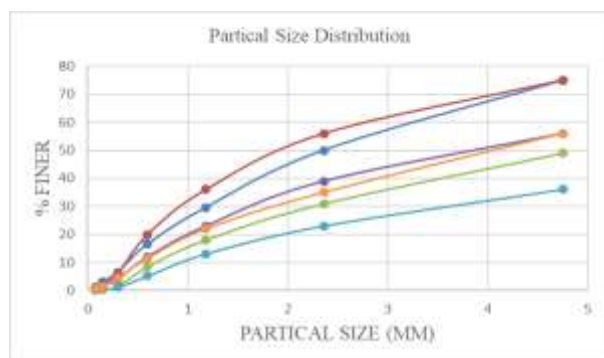


Fig 3. Particle Size Distribution

The above figure 4.1 illustrates the particle size distribution curve obtained from the sieve analysis test, which represents the percentage of soil particles passing

through different sieve sizes. The horizontal axis shows the particle size in millimeters, while the vertical axis represents the percentage finer (% passing). From the graph, it can be observed that the percentage of finer particles gradually increases as the particle size increases. At smaller particle sizes below 0.5 mm, only a small proportion of particles pass through the sieve, indicating the presence of fine soil fractions. As the particle size approaches 1 mm, the percentage finer increases to approximately 30–35%, showing the presence of medium-sized particles. At around 2.5 mm particle size, the percentage passing ranges between 35% and 55% for different samples. Finally, at the largest particle size of approximately 4.75 mm, the percentage finer reaches nearly 50% to 75%, indicating that a significant portion of soil particles falls within this size range. This particle size distribution helps classify the soil and understand its gradation characteristics for engineering applications.

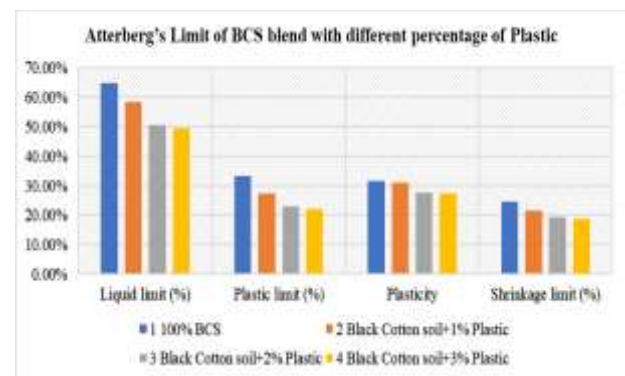


Fig 4. Atterberg's Limit of BCS blend with different percentage of Bagasse

As shown in above figure 4.2, The Atterberg limits of Black Cotton Soil (BCS) blended with different percentages of plastic waste, showing the influence of plastic on soil consistency characteristics. For the natural soil (100% BCS), the liquid limit is 64.70%, plastic limit is 33.24%, plasticity index is 31.68%, and shrinkage limit is 24.51%, indicating high plasticity typical of expansive black cotton soil. When 1% plastic is added, the liquid limit decreases to 58.36%, the plastic limit reduces to 27.32%, and the shrinkage limit becomes 21.41%, showing an improvement in soil stability. With 2% plastic, the liquid limit further decreases to 50.66%, plastic limit to 22.95%, and shrinkage limit to 19.31%, indicating reduced plastic behavior. At 3% plastic content, the liquid limit is 49.49%, plastic limit 22.01%, plasticity index 27.48%, and shrinkage limit 18.73%. Overall, Table 4.3 clearly shows that increasing plastic content reduces the plasticity and swelling characteristics

of black cotton soil, thereby improving its engineering properties for stabilization applications.

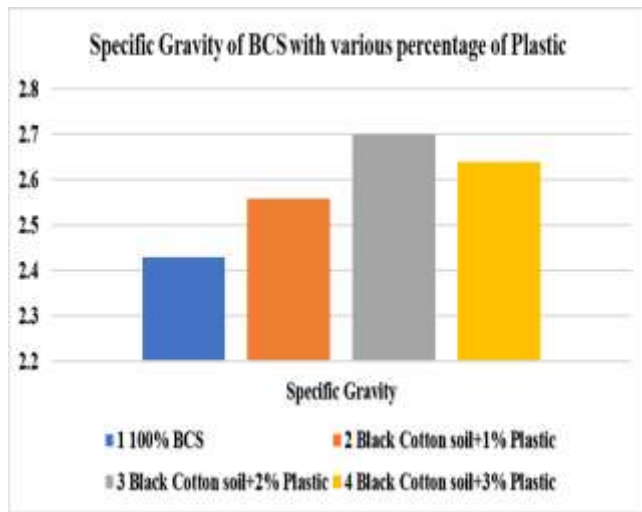


Fig 5. Specific Gravity of BCS with various percentage of Bagasse

As shown in above figure 4.3, the variation in specific gravity of Black Cotton Soil (BCS) mixed with different percentages of plastic waste. The specific gravity of the natural soil (100% BCS) is 2.43, which represents the basic density characteristics of the untreated soil. When 1% plastic is added to the soil, the specific gravity increases to 2.56, indicating an improvement in the density characteristics of the soil mixture. With the addition of 2% plastic, the specific gravity further increases to 2.70, which represents the highest value observed in this study. This increase suggests better particle interaction and improved soil structure due to the presence of plastic particles. However, when the plastic content increases to 3%, the specific gravity slightly decreases to 2.64. This reduction may occur due to excess plastic particles creating voids within the soil matrix. Overall, Table 4.4 indicates that the optimum plastic content is around 2%, where the soil mixture shows the maximum specific gravity and improved soil properties for stabilization purposes.

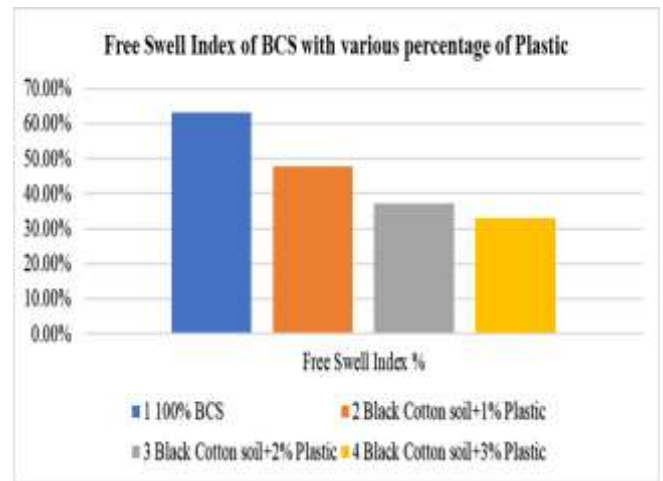


Fig 6. Free Swell Index of BCS with various percentage of Bagasse

As shown in above figure 4.4, the variation in Free Swell Index (FSI) of Black Cotton Soil (BCS) with different percentages of plastic waste. The natural soil (100% BCS) shows a Free Swell Index of 63.33%, indicating a high swelling potential typical of expansive black cotton soil. When 1% plastic is added, the Free Swell Index reduces significantly to 48%, showing an improvement in soil stability. With 2% plastic content, the Free Swell Index further decreases to 37.33%, indicating that the swelling behavior of the soil is gradually controlled. At 3% plastic content, the Free Swell Index reaches 33%, which is the lowest value observed in the study. This continuous reduction in swelling potential occurs because plastic particles restrict the expansion of clay minerals within the soil structure. Overall, Table 4.5 clearly indicates that increasing plastic content effectively reduces the swelling characteristics of black cotton soil, thereby improving its suitability for geotechnical and pavement construction applications.

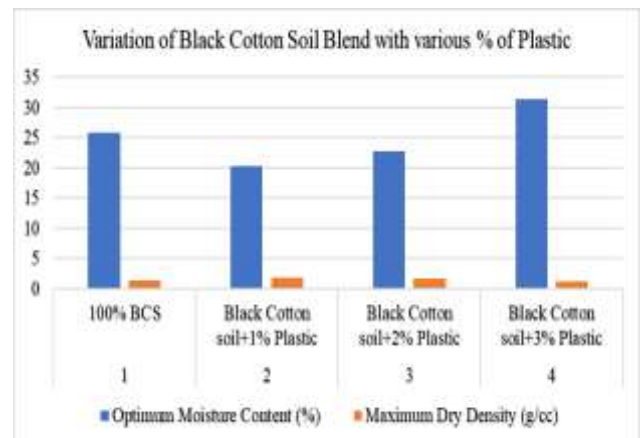


Fig 7. Variation of Black Cotton Soil Blend with various % of Plastic

Table 4.6 presents the compaction parameters of Black Cotton Soil (BCS) blended with different percentages of plastic waste, obtained from the Modified Proctor test. The natural soil (100% BCS) shows an Optimum Moisture Content (OMC) of 25.84% and a Maximum Dry Density (MDD) of 1.32 g/cc, indicating moderate compaction characteristics of untreated soil. When 1% plastic is added, the OMC decreases to 20.33% while the MDD increases significantly to 1.74 g/cc, showing improved compaction and density of the soil mixture. With 2% plastic content, the OMC slightly increases to 22.71% and the MDD reduces to 1.64 g/cc, but still remains higher than the natural soil. However, when the plastic content increases to 3%, the OMC rises sharply to 31.32% and the MDD drops to 1.19 g/cc, indicating poor compaction due to excessive plastic particles. Therefore, Table 4.6 suggests that the optimum plastic content is around 1%, where the soil achieves maximum dry density and better compaction characteristics.

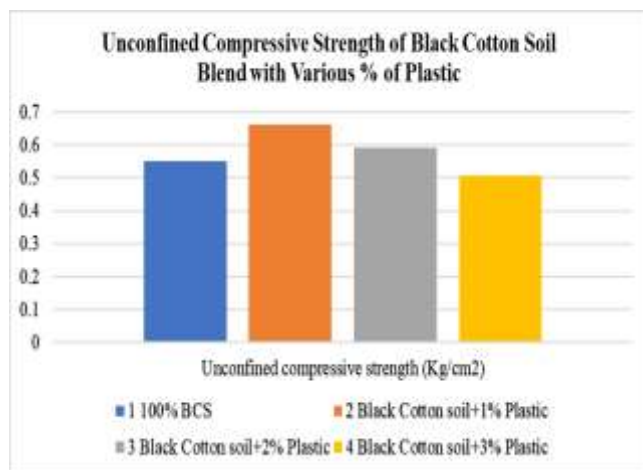


Fig 8. Unconfined Compressive Strength of Black Cotton Soil Blend with Various % of Plastic

Figure 4.6 presents the Unconfined Compressive Strength (UCS) values of Black Cotton Soil (BCS) blended with different percentages of plastic waste, which indicates the variation in soil strength due to stabilization. The natural soil (100% BCS) shows a UCS value of 0.550 kg/cm², representing the basic shear strength of untreated black cotton soil. When 1% plastic is added to the soil, the UCS value increases to 0.662 kg/cm², indicating a significant improvement in soil strength due to the reinforcing effect of plastic particles within the soil matrix. With 2% plastic content, the UCS value slightly decreases to 0.592 kg/cm², but it still remains higher than the untreated soil, showing moderate improvement. However, when the plastic content increases to 3%, the UCS value further decreases to 0.508 kg/cm², which is lower than the natural soil. This reduction occurs because excessive plastic

reduces bonding between soil particles. Therefore, Table 4.7 indicates that 1% plastic content provides the optimum strength improvement.

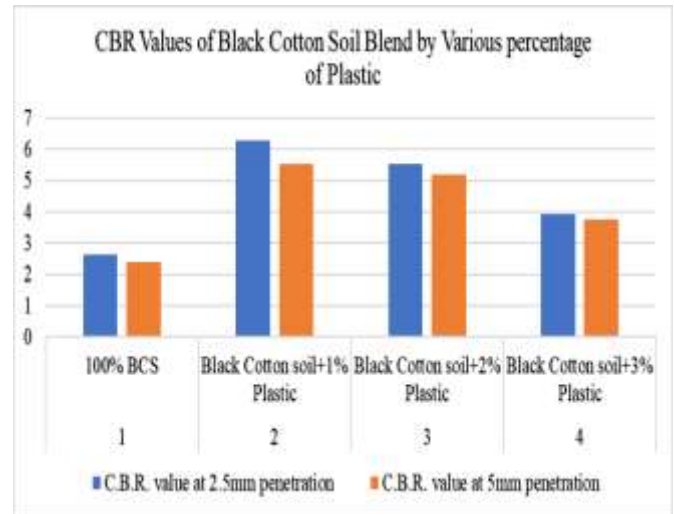


Fig 9. CBR Values of Black Cotton Soil Blend by Various percentage of Plastic

As shown in above figure, the California Bearing Ratio (CBR) values of Black Cotton Soil (BCS) blended with different percentages of plastic waste at 2.5 mm and 5 mm penetration levels. The natural soil (100% BCS) shows a CBR value of 2.63% at 2.5 mm penetration and 2.4% at 5 mm penetration, indicating low load-bearing capacity typical of expansive black cotton soil. When 1% plastic is added, the CBR value increases significantly to 6.3% at 2.5 mm penetration and 5.52% at 5 mm penetration, showing a major improvement in soil strength and stability. With 2% plastic content, the CBR values slightly decrease to 5.52% and 5.2%, but they are still higher than the natural soil. However, when 3% plastic is added, the CBR values reduce to 3.94% and 3.76%, indicating a decline in strength due to excessive plastic content. Therefore, Table 4.8 indicates that 1% plastic content provides the maximum improvement in load-bearing capacity of the soil.

V. CONCLUSION

Plastic waste management has become a critical environmental and engineering challenge due to the rapid increase in plastic consumption and the non-biodegradable nature of plastic materials. The experimental study focused on the utilization of waste plastic in black cotton soil stabilization for pavement construction, demonstrating both engineering and environmental benefits. The results show that the addition of 1%, 2%, and 3% plastic waste increased the CBR values from 6% to 8%, significantly improving the load-

bearing capacity of expansive soils. As the CBR value increased, the total pavement thickness reduced from 622.5 mm to 557.5 mm, which directly decreased the requirement of structural layers such as Wet Mix Macadam and Dense Bituminous Macadam. According to the cost evaluation using SSR 2024–2025 rates, the pavement construction cost also reduced, with the total cost decreasing to ₹16,304,208 for higher CBR values, indicating the economic feasibility of plastic-stabilized pavement systems.

The results demonstrate that the reuse of plastic waste in black cotton soil stabilization significantly improves engineering properties while providing substantial environmental benefits. The Free Swell Index reduced from 63.33% to 33%, indicating improved soil stability and reduced expansion potential. Similarly, the CBR value increased from 2.63 to 6.3 and UCS strength improved from 0.550 kg/cm² to 0.662 kg/cm², confirming enhanced load-bearing capacity and shear strength suitable for pavement construction. Environmental assessment shows that plastic reuse generates 86.58 kg CO₂/ton during processing, which is significantly lower than emissions from conventional disposal methods, achieving an emission reduction of 53.42 kg CO₂ per ton. Risk assessment further highlights that improper plastic disposal leads to high environmental risks such as soil contamination, water pollution, and landfill overflow. Therefore, integrating plastic waste into soil stabilization reduces environmental hazards, improves pavement performance, lowers construction costs, and promotes sustainable and environmentally responsible infrastructure development.

An environmental perspective, the reuse of plastic waste in pavement construction provides an effective solution for reducing landfill accumulation, minimizing open burning of plastics, and conserving natural construction materials. The integration of plastic waste into soil stabilization not only improves pavement performance but also supports sustainable infrastructure development and circular economy principles. The Bill of Materials analysis further confirms that the use of plastic-modified materials reduces overall material consumption while maintaining structural performance according to IRC 37–2018 pavement design standards. Therefore, adopting plastic waste in pavement engineering can significantly contribute to environmentally responsible waste management practices while enhancing pavement durability and reducing long-term construction costs.

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