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Construction And Demolition Waste Used in Stabilization of Expansive Soil in Road Subgrades- A Review

Mr. Pranav K. Bhosale [1], Ms. Apeksha Choudhary [2]

[1] Research Scholar, Civil Engineering Department, G H Raisoni University, Amravati, Maharashtra, India
[2] Assistant Professor, Civil Engineering Department, G H Raisoni University, Amravati, Maharashtra, India

Corresponding Author-
Name: Pranav Kakaso Bhosale
E-mail Id: pranav.bhosale1995@gmail.com

Abstract- The rapid growth of construction activities has led to the generation of large quantities of construction and demolition waste (CDW), which poses serious environmental challenges due to improper disposal. At the same time, expansive soils such as black cotton soil exhibit poor engineering properties including high swelling, shrinkage, and low bearing capacity, making them unsuitable for road subgrade applications. In recent years, researchers have explored the use of CDW as a sustainable alternative for soil stabilization. This review paper presents a comprehensive analysis of previous studies on the use of CDW and other waste materials such as plastic waste, ceramic powder, and industrial by-products for stabilizing expansive soils. The findings from various studies indicate that CDW materials such as brick powder, crushed concrete, and recycled aggregates significantly improve soil properties by increasing strength, reducing plasticity, and enhancing compaction characteristics. Several studies reported improvement in California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS), making stabilized soil suitable for pavement applications [1], [12]. The review also highlights that the use of CDW reduces environmental pollution, minimizes landfill disposal, and conserves natural resources. However, variations in material properties, lack of standardized mix proportions, and limited field studies remain key challenges. Overall, the utilization of CDW in soil stabilization is an economical, eco-friendly, and sustainable approach for improving weak subgrade soils.

Keywords: Construction and Demolition Waste, Soil Stabilization, Expansive Soil, Black Cotton Soil, CBR, Sustainable Construction, Subgrade.

I. INTRODUCTION

Expansive soils are one of the most problematic types of soils encountered in civil engineering, particularly in the construction of roads, foundations, and embankments. Among these, black cotton soil is widely found in many parts of India, especially in regions like Maharashtra, Madhya Pradesh, and Gujarat. This soil is characterized by its high swelling and shrinkage properties due to the presence of minerals such as montmorillonite. When exposed to water during the rainy season, the soil absorbs moisture and expands significantly, whereas during dry conditions, it shrinks and forms deep cracks. This continuous volume change leads to severe engineering problems such as pavement distortion, cracking, differential settlement, and reduction in structural stability [19].

Due to these unfavorable properties, black cotton soil exhibits low bearing capacity and poor load-supporting characteristics, making it unsuitable for direct use as a subgrade material in road construction. The performance of pavement structures largely depends on the strength and stability of the subgrade soil. Weak subgrade conditions often result in increased maintenance costs, reduced service life of pavements, and frequent structural failures. Therefore, improving the engineering properties of such soils through stabilization techniques becomes essential for ensuring safe and durable infrastructure development [19].

Traditionally, soil stabilization has been carried out using materials such as cement, lime, and bitumen. These materials are effective in improving soil strength and reducing plasticity; however, they are associated with certain disadvantages. The production of cement and lime involves high energy consumption and results in significant emission of greenhouse gases, contributing to environmental pollution. Additionally, the cost of these stabilizing agents is relatively high, making them less economical for large-scale applications, especially in developing countries. Hence, there is a growing need to explore alternative, low-cost, and environmentally friendly materials for soil stabilization [19], [20].

In parallel with the challenges of weak soils, rapid urbanization and infrastructure development have led to the generation of enormous quantities of construction and demolition waste (CDW). This waste is produced during activities such as construction, renovation, repair, and demolition of buildings, roads, bridges, and other structures. CDW mainly consists of materials like concrete, bricks, mortar, plaster, metals, wood, glass, and plastics. In India, the generation of CDW has increased drastically in recent years, but only a small fraction of this waste is recycled or reused, while the majority is disposed of in landfills or open dumping sites [1].

Improper disposal of construction and demolition waste creates serious environmental issues. It leads to land degradation, air pollution due to dust, contamination of soil and groundwater, and blockage of drainage systems, which may cause urban flooding. Moreover, it occupies valuable land space and contributes to unsanitary conditions in both urban and rural areas. Therefore, effective management and utilization of CDW have become critical for sustainable development in the construction industry [1].

To address both the problems of weak expansive soils and waste disposal, researchers have increasingly focused on the use of construction and demolition waste as a stabilizing material. CDW contains materials such as crushed concrete, brick powder, and recycled aggregates, which possess suitable engineering properties. These materials can act as fillers and binding agents when mixed with soil, thereby improving its gradation, density, and strength characteristics. Studies have shown that the addition of CDW reduces the plasticity index, increases maximum dry density, and improves California Bearing Ratio (CBR) values, making the soil more suitable for subgrade applications [12], [14].

Brick powder, in particular, has gained significant attention due to its pozzolanic properties and easy availability from demolished structures. When mixed with expansive soil, brick powder helps in reducing swelling potential and improving compaction behavior. It enhances inter-particle bonding and reduces void spaces, resulting in improved strength and stability of soil. Additionally, the use of CDW reduces dependence on natural construction materials and minimizes the environmental impact associated with their extraction [12], [14].

Furthermore, the use of CDW in soil stabilization offers multiple benefits, including cost reduction, resource conservation, and environmental protection. It provides a sustainable solution by converting waste materials into useful construction resources. This approach aligns with the principles of green construction and circular economy, where waste materials are reused and recycled to minimize environmental impact. Several studies have demonstrated that the use of CDW can significantly improve soil properties while reducing construction costs and promoting sustainable infrastructure development [1], [12].

II. LITERATURE REVIEW

Numerous studies have been conducted in recent years to evaluate the effectiveness of construction and demolition waste (CDW) and other waste materials in soil stabilization, particularly for expansive soils such as black cotton soil. The increasing demand for sustainable construction practices has encouraged researchers to explore alternative materials that can improve soil properties while minimizing environmental impact. The following section presents a detailed review of relevant literature in this field. Shuvo et al. (2026) conducted a comprehensive review on the geotechnical applications of construction and demolition waste and highlighted its potential in various engineering applications such as subgrade stabilization, embankments, and pavement layers. The study reported that CDW materials like recycled concrete aggregates and crushed bricks significantly improve soil strength, permeability, and compaction characteristics. Additionally, the use of CDW was found to reduce swelling and compressibility of expansive soils. One of the key findings of this study was that CDW can reduce construction costs by 30–50% while also contributing to environmental sustainability by reducing landfill waste and conserving natural resources [1].

Mahale et al. (2025) focused on the use of brick waste in rural road pavement design. The study demonstrated that the inclusion of brick waste improves the load-bearing capacity of soil and significantly increases California Bearing Ratio (CBR) values. This improvement in CBR leads to a reduction in pavement thickness and overall construction cost. The authors emphasized that brick waste acts as an effective filler material, improving soil gradation and strength, making it suitable for subgrade applications in low-cost road construction [2].

Deepak et al. (2025) explored the use of recycled PET plastic waste as a stabilizing material for black cotton soil. The study found that the addition of plastic waste improves shear strength and bearing capacity up to an optimum percentage, beyond which the performance begins to decline. The results also showed improvement in compaction characteristics, indicating that plastic waste can be used as an effective and sustainable alternative stabilizer. This approach also helps in reducing plastic pollution, thereby addressing environmental concerns [3].

Isik (2025) investigated the use of CDW-based geopolymer for stabilizing clay soils. The study revealed that the use of geopolymer significantly enhances soil strength, with Unconfined Compressive Strength (UCS) increasing up to 14 times after curing. The formation of strong chemical bonds and dense microstructure was confirmed through advanced analysis techniques such as SEM and XRD. This study highlights the potential of CDW-based geopolymer as an advanced and sustainable stabilizing material [4].

Tanyıldızı and Gökalp (2025) studied the effect of waste paper sludge (WPS) on expansive soils. The results indicated that WPS improves the resilient modulus and stiffness of soil, making it suitable for pavement applications. The study also utilized artificial neural network (ANN) models to predict soil behavior, which showed high accuracy. The findings suggest that WPS is an effective stabilizing material that enhances both strength and durability of soil [5].

Barisoglu et al. (2025) developed predictive models for soil stabilization using CDW and conducted extensive laboratory testing on multiple soil samples. The study found that strength and stiffness of soil increase with proper mix design, curing time, and water-cement ratio. The use of ANN models provided accurate predictions of soil properties, reducing the need for extensive laboratory testing. This research highlights the importance of optimized mix design in achieving better stabilization results [6].

Chavan et al. (2025) investigated the use of waste plastic materials such as plastic bottles and tire scraps for soil stabilization. The results showed that plastic waste improves shear strength, dry density, and load-bearing capacity of soil. Additionally, the use of plastic waste helps in reducing environmental pollution and promotes recycling. The study concluded that plastic waste is an economical and eco-friendly stabilizing material for expansive soils [7].

Xu and Huang (2025) studied the long-term performance of CDW-stabilized soil under wetting–drying cycles. The study found that although some strength degradation occurs during repeated cycles, the stabilized soil performs significantly better than untreated soil. The optimum CDW content was found to be around 40%, which provided the best performance in terms of strength and stiffness. This study emphasizes the importance of evaluating long-term durability of stabilized soils [8].

Thenmozhi and Mohan (2024) examined the use of ceramic powder as a stabilizing material. The results showed that ceramic powder reduces plasticity and increases CBR values, leading to improved load-bearing capacity. The study also reported a reduction in pavement thickness and construction cost, demonstrating the effectiveness of ceramic powder as a sustainable stabilizer [9].

Galindo et al. (2024) used advanced optimization techniques to determine the best combination of soil, CDW, and steel slag. The study found that the optimized mix significantly improves strength, durability, and overall performance of soil. The use of CDW and industrial by-products also promotes sustainable construction practices and reduces environmental impact [10].

Gupta et al. (2023) conducted experimental studies on soil stabilization using CDW and reported a significant increase in CBR values from 3.82% to 14.04%. This improvement indicates that CDW can effectively enhance subgrade performance and reduce pavement thickness. The study also confirmed that stabilized soil meets Indian Standard requirements for construction [12].

Pazare et al. (2023) investigated the use of recycled CDW in black cotton soil and observed that it improves soil strength and reduces environmental impact. The study highlighted that CDW is a sustainable alternative to conventional stabilizers and can be effectively used in road construction [13].

Ujile and Abbey (2022) reviewed the use of fine portions of CDW and concluded that these materials act as fillers, improving soil density and reducing swelling behavior. The study emphasized that proper processing and selection of CDW materials are essential for achieving optimal performance [14].

Makode et al. (2022) studied the effect of CDW on black cotton soil and found that it enhances strength parameters such as shear strength and bearing capacity. The study also highlighted that CDW provides an economical alternative to traditional stabilizers [15].

Reddy et al. (2022) investigated the stabilization of clayey soil using CDW and reported that optimum addition improves UCS and CBR values. However, excessive addition of CDW leads to a reduction in strength, indicating the importance of determining optimum proportions [16].

Prajapati et al. (2022) reported significant improvement in compaction characteristics and bearing capacity of soil with the addition of CDW. The study demonstrated that CDW can effectively replace a portion of natural soil in subgrade applications [17].

Patil et al. (2021) concluded that CDW improves soil strength, particularly when coarser fractions are used. The study emphasized that particle size plays a crucial role in stabilization effectiveness [18].

Singh et al. (2021) provided a comprehensive review of soil stabilization using CDW and highlighted that it reduces plasticity, improves compaction, and enhances strength characteristics. The study emphasized the importance of sustainable waste utilization [19].

Dhakal and Chopra (2020) demonstrated that lime-treated demolition waste can be effectively used in road base layers. The study showed that lime treatment enhances strength and stiffness, making the material comparable to natural aggregates [20].

Varaprasad et al. (2019) found that CDW reduces swelling and improves strength of expansive soils. The study also reported improved bonding and reduced voids in stabilized soil [21].

Vivek et al. (2018) reported that optimum addition of CDW improves cohesion, internal friction angle, and bearing capacity of soil. The study confirmed that CDW is effective in reducing swelling behavior [23].

Kumar and Rathod (2018) concluded that demolished concrete waste improves soil gradation and strength due to its cementitious properties. The study emphasized its potential as a low-cost stabilizer [24].

Ravikanth et al. (2017) demonstrated that debris material improves soil density and engineering properties. The study highlighted that demolition waste can be effectively used for soil stabilization in a cost-effective manner [25].

III. RESEARCH GAP

Based on the comprehensive review of literature on soil stabilization using construction and demolition waste (CDW) and other waste materials, it is evident that significant progress has been made in improving the engineering properties of expansive soils. Various studies have demonstrated that CDW materials such as brick powder, crushed concrete, and recycled aggregates can effectively enhance strength, reduce plasticity, and improve compaction characteristics of soil. Improvements in parameters such as California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) have also been widely reported, indicating the suitability of CDW-stabilized soil for pavement subgrade applications [12], [14]. However, despite these advancements, several research gaps still exist that need to be addressed to ensure the effective and large-scale implementation of CDW in soil stabilization. Firstly, most of the studies available in the literature are primarily limited to laboratory-scale investigations, with very few field-level studies conducted to validate the performance of stabilized soil under actual site conditions.

Long-term performance evaluation, especially under varying environmental conditions such as wetting–drying cycles and seasonal moisture variations, has not been extensively studied [8]. Secondly, there is a lack of standardized guidelines or specifications regarding the optimum percentage of CDW to be used for different soil types. While several researchers have reported optimum values ranging from 10% to 50%, these values vary significantly depending on soil characteristics, type of waste material, and testing conditions. This variation creates uncertainty in practical applications and highlights the need for developing standardized design procedures [16].

Another important gap is the limited focus on specific materials such as brick powder for stabilization of black cotton soil under Indian conditions. Although some studies have explored the use of CDW in general, detailed investigations on the behavior of brick powder as a stabilizing agent, including its effect on swelling, compressibility, and durability, are still insufficient [14].
Furthermore, most research studies have focused on individual engineering properties such as CBR or UCS, but very few studies have comprehensively evaluated all relevant parameters including Atterberg limits, compaction characteristics, strength properties, and swelling behavior together. A holistic evaluation is necessary to fully understand the performance of stabilized soil in real-world applications.

In addition, economic analysis and cost-benefit evaluation of using CDW in soil stabilization have not been adequately addressed in many studies. While it is generally accepted that CDW is a cost-effective alternative, detailed analysis considering transportation, processing, and construction costs is required to support its practical implementation [12].

Another gap identified is the variability in properties of construction and demolition waste. Since CDW is obtained from different sources such as buildings, roads, and industrial structures, its composition and properties may vary significantly. This variability affects the consistency and reliability of results, and therefore, proper classification and characterization of CDW materials are required before their use in stabilization. Moreover, limited research has been carried out on the environmental impact assessment of using CDW in soil stabilization. Although it is considered an eco-friendly approach, detailed studies on leachability, long-term environmental effects, and sustainability assessment are still lacking. Therefore, in view of the above research gaps, the present study focuses on the stabilization of black cotton soil using brick powder obtained from construction and demolition waste. The study aims to evaluate the effect of different proportions of brick powder on various engineering properties of soil and to identify the optimum mix for improving subgrade performance in a sustainable and economical manner.

CONCLUSION

Based on the comprehensive review of literature on the stabilization of expansive soils using construction and demolition waste (CDW) and other alternative materials, it can be concluded that CDW is an effective, economical, and sustainable stabilizing agent for improving the engineering properties of problematic soils such as black cotton soil. Various studies have demonstrated that the incorporation of CDW materials such as brick powder, crushed concrete, and recycled aggregates leads to significant improvements in soil strength, compaction characteristics, and load-bearing capacity. The review indicates that the addition of CDW reduces the plasticity index and swelling behavior of expansive soils, thereby minimizing volume changes and improving stability. At the same time, parameters such as Maximum Dry Density (MDD), California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS) show considerable improvement with the inclusion of optimum proportions of CDW. These enhancements make the stabilized soil suitable for use in pavement subgrade, embankments, and other geotechnical applications [12], [14]. Several researchers have also highlighted that CDW acts as a filler material, improving soil gradation and reducing voids, which contributes to better compaction and strength development. In addition, the presence of cementitious compounds in certain CDW materials promotes bonding between soil particles, further enhancing mechanical properties. However, it has been observed that beyond an optimum percentage, the addition of CDW may lead to a reduction in strength, emphasizing the importance of proper mix design [16]. From an environmental perspective, the use of CDW in soil stabilization offers significant advantages. It helps in reducing the burden on landfills, minimizing environmental pollution, and conserving natural resources by replacing conventional construction materials. This approach supports sustainable development and aligns with modern concepts such as green construction and circular economy. Additionally, it provides a cost-effective solution by reducing the need for expensive stabilizers like cement and lime, thereby lowering overall construction costs [1]. Despite these benefits, certain limitations have been identified, such as variability in the properties of CDW, lack of standardized guidelines, and limited field-scale studies.

Long-term performance under environmental conditions such as wetting–drying cycles also requires further investigation. Therefore, more research is needed to establish reliable design standards and to evaluate the durability of stabilized soil in real-life conditions. In conclusion, construction and demolition waste has great potential as a sustainable stabilizing material for expansive soils. Its effective utilization not only improves soil performance but also addresses the growing problem of waste management. With proper mix design, quality control, and further research, CDW can play a significant role in the development of durable, economical, and environmentally friendly infrastructure.

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