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Optimization of Black Cotton Soil Stabilization Using Lime and Bamboo Fiber Mixture for Sustainable Road Subgrade Construction - A Review

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Abstract- Black cotton soil is highly expansive and poses serious challenges in civil engineering due to its swelling and shrinkage behavior. Stabilization of such soil is essential for improving its engineering properties and making it suitable for construction applications. This review paper presents a comprehensive analysis of previous research studies on stabilization of black cotton soil using lime, bamboo fiber, construction and demolition waste (CDW), and other sustainable materials. The study highlights the effectiveness of chemical stabilization using lime and mechanical reinforcement using fibers. Various experimental investigations indicate that lime reduces plasticity and improves strength, while fibers enhance ductility and resistance to cracking. The paper also identifies key research gaps related to combined stabilization techniques and optimization of material proportions. The review concludes that the combined use of lime and bamboo fiber offers a promising, cost-effective, and sustainable solution for improving subgrade performance.

Keywords: Black Cotton Soil, Soil Stabilization, Lime, Bamboo Fiber, CBR, UCS, Sustainable Construction, Subgrade.

I. INTRODUCTION

Black cotton soil is one of the most problematic soils in civil engineering due to its high swelling and shrinkage characteristics caused by the presence of montmorillonite minerals. These properties lead to cracking, settlement, and failure of pavements and foundations. Stabilization of such soils is necessary to improve their strength, durability, and load-bearing capacity. Various stabilization techniques have been developed over the years, including chemical stabilization using lime and cement, mechanical stabilization using fibers, and utilization of industrial and construction waste materials. Among these, lime stabilization is widely used due to its effectiveness in reducing plasticity and improving strength. Similarly, natural fibers such as bamboo have gained attention due to their eco-friendly nature and ability to enhance soil strength and ductility. This review paper aims to analyze previous research works on soil stabilization and identify research gaps for further investigation, particularly focusing on the combined use of lime and bamboo fiber.

II. LITERATURE REVIEW

[1] Performance Assessment of Bamboo and Sisal Fiber Reinforcement in Red Ash Stabilized Expansive Black Cotton Soil (2026) by Lemlemu Bizualem and Frehaileab Admasu Gidebo – investigated the behavior of expansive black cotton soil stabilized using bamboo fiber, sisal fiber, and red ash with an emphasis on improving geotechnical performance. The authors highlighted that black cotton soil exhibits severe swelling and shrinkage characteristics along with low compressive strength and weak shear resistance, making it unsuitable for construction without stabilization. The study involved the addition of bamboo fiber, sisal fiber, and their combination with red ash in varying proportions (0.45%, 0.9%, 1.8%, and 2.7% by dry weight of soil).

The samples were compacted at optimum moisture content and maximum dry density, and tests such as compaction, direct shear, unconfined compressive strength (UCS), and free swell index were conducted. The results indicated that sisal fiber at 1.8% content provided the highest improvement in strength, with UCS values reaching 225.27 kPa (0 days curing) and 247.46 kPa (after 7 days curing), along with improved shear strength parameters such as cohesion (72.87 kPa) and angle of internal friction (29.1°). Bamboo fiber demonstrated better compaction characteristics, achieving a maximum dry density of 1.24 g/cc and the lowest optimum moisture content of 31.41% at 0.45% fiber content.

[2] Geotechnical Applications of Construction and Demolition Waste and Future Prospects in Bangladesh – A Comprehensive Review (2026) by Bishal Paul Shuvo, Davashis Deb, Tania Ahmed Smrity, Junaidul Islam, and Shriful Islam – studied the use of construction and demolition waste (CDW) in various geotechnical applications with a focus on sustainability, economic benefits, and environmental protection. The authors explained that due to rapid urbanization and infrastructure development, a huge amount of CDW is generated worldwide, and a large portion of it is dumped in landfills, causing environmental problems such as land degradation, pollution, and depletion of natural resources. The study reviewed the properties of CDW materials like recycled concrete aggregate (RCA), crushed brick (CB), and recycled asphalt pavement (RAP), and found that these materials can be effectively used in applications such as pavement layers, subgrade stabilization, embankments, slope stability, shallow foundations, and riverbank protection.

[3] Stabilization of Black Cotton Soil Using Lime and Bamboo Fiber Mixture as a Subgrade Material (2025) by Kankate Rohan Popat, Vithal Vilas Kale, Netake Swapnil Sitaram, and Prof. S. S. Patil – studied the improvement of engineering properties of black cotton soil using lime and bamboo fiber as stabilizing agents. The authors highlighted that black cotton soil exhibits high swelling and shrinkage behavior, which leads to severe damage in pavements and structures. The study involved the addition of lime in varying proportions (2%, 4%, 6%, and 8%) to determine the optimum lime content based on laboratory tests such as Atterberg limits, Modified Proctor test, Free Swell Index, California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS). It was observed that 6% lime content provided optimum stabilization by significantly improving strength and reducing plasticity.

[4] Review on Stabilization Techniques for Black Cotton Soil Using Various Materials (2025) by Gurusharan Mishra – presented a comprehensive review of different stabilization techniques used for improving the engineering properties of black cotton soil. The author highlighted that black cotton soil, due to its high montmorillonite content, exhibits excessive swelling, shrinkage, low bearing capacity, and poor shear strength, making it unsuitable for construction applications, especially in road subgrades. The study synthesized findings from 18 research works spanning from 1996 to 2025, focusing on various stabilization methods including chemical stabilization (lime, cement), mechanical reinforcement (fibers, geosynthetics), industrial waste utilization (fly ash, copper slag, flue gas desulfurization gypsum, construction and demolition waste), and bio-enzyme techniques such as Terazyme.

[5] Rural Road Pavement Design Using Construction Brick Waste (2025) by Sainath Harish Mahale, Keshraj Shankar Bhadane, Surekha S. Thorat, Vishakha Yuvraj Pagare, and Vijay Dnyaneshwar Ranpise – studied the use of construction brick waste for improving the properties of local soil in rural road pavement design with the aim of developing an economical and sustainable solution. The authors explained that in India, rural road infrastructure is very important for economic growth and connectivity, but locally available soils often do not have sufficient strength to support traffic loads. Therefore, stabilization techniques are required to improve subgrade performance. In this study, crushed brick waste was used as a stabilizing material by mixing it with soil in different proportions such as 10%, 20%, 30%, and 40%, and laboratory tests like liquid limit, plastic limit, grain size distribution, compaction test, and California Bearing Ratio (CBR) were conducted to evaluate the soil properties.

[6] Sustainable Stabilization of Expansive Black Cotton Soil Using Recycled PET Plastic Waste for Flexible Pavement Subgrade: An Experimental Approach (2025) by Deepak G. B., Mohmmad Sayeed M., S. Poornachandra Thejaswi, Sreekeshava K., Prashant Sunagar, and T. Naga Seshubabu – studied the stabilization of black cotton soil using recycled PET plastic waste as an innovative and sustainable material to improve soil properties for pavement subgrade applications. The authors explained that expansive soils like black cotton soil create serious problems in construction due to swelling, shrinkage, and low bearing capacity, which can lead to pavement failure and structural damage. Traditional stabilizers like cement and lime are effective but costly and environmentally harmful, so there is a need for alternative eco-friendly materials. In this study, shredded plastic waste was used as a soil stabilizer, and laboratory tests such as sieve analysis, Modified Proctor compaction test, and California Bearing Ratio (CBR) test were conducted to evaluate the engineering properties of stabilized soil.

[7] Experimental Study on Compressive Strength of Clay Soil Stabilized with Construction and Demolition Waste-Based Geopolymer (2025) by Adem Isik – studied the stabilization of clay soil using construction and demolition waste (CDW) based geopolymer as a binding material to improve soil strength and performance. The author explained that traditional stabilizers like cement and lime have environmental impacts, so there is a need for alternative sustainable materials such as geopolymers made from recycled construction waste. In this study, different proportions of CDW-based geopolymer were used along with varying curing periods and alkali activator concentrations to evaluate their effect on soil strength. Laboratory tests such as Unconfined Compressive Strength (UCS) were conducted, and the results showed a significant improvement in soil strength, where UCS values increased approximately 8.1 times after 7 days, 12.2 times after 28 days, and 14.6 times after 91 days compared to untreated soil.

[8] Stabilization of Expansive Road Subgrades with Waste Paper Sludge: Resilient Modulus, ANN and Modeling Approach (2025) by Muhammed Tanyıldızı and İslam Gökalp – studied the stabilization of expansive soil using waste paper sludge (WPS) for road subgrade applications with a focus on sustainable construction. The authors explained that stabilization of expansive soil is very important in transportation engineering because such soils show swelling and shrinkage behavior and have low bearing capacity, which leads to pavement failure. In this study, the effect of waste paper sludge on three different types of expansive soils was investigated by conducting repeated load tests to determine the resilient modulus (Mr), which is an important parameter for pavement design. The researchers mixed different percentages of WPS with soil and observed that the resilient modulus values increased significantly with the addition of WPS up to an optimum value of about 9%, indicating improved stiffness and strength of the soil.

[9] Utilising Construction and Demolition Waste in Soft Soil Stabilisation: A Prediction Model for Enhanced Strength and Stiffness (2025) by **Ecem Nur Barisoglu, Taher Ghalandari, Diederik Snoeck, Ramiro Daniel Verástegui-Flores, and Gemmina Di Emidio** – studied the use of construction and demolition waste (C&DW) in stabilizing soft soils such as peat and clay with a focus on improving strength and stiffness along with sustainable construction practices. The authors explained that the use of recycled materials like C&DW in soil stabilization helps in reducing environmental problems such as waste disposal, resource depletion, and pollution, while also improving soil performance. In this study, a large number of laboratory tests were conducted on more than 296 soil samples to evaluate important engineering properties such as Unconfined Compressive Strength (UCS), Young's modulus, and shear modulus. Different parameters like cement content, recycled material content, curing time (28, 60, 90, and 120 days), and water-cement ratio were considered to understand their effect on soil behavior.

[10] Application of Waste Plastic Material Used in Soil Stabilization (2025) by **Chavan Swapnil Anil, Batwal Siddhesh Sandeep, Pawar Jivan Balu, Auti Shravan Vilas, Prof. Shinde O. P., and Prof. Vighe S. T.** – studied the use of waste plastic materials such as plastic bottles and tire scraps for stabilization of soil, especially black cotton soil, to improve its engineering properties and performance in construction. The authors explained that black cotton soil is highly expansive and shows swelling and shrinkage behavior, which leads to problems like settlement and failure of structures, so stabilization is necessary. Traditional stabilizers like cement, lime, and fly ash are effective but costly and have environmental impacts, so the study focused on using plastic waste as an alternative sustainable material. Laboratory tests such as California Bearing Ratio (CBR), Proctor compaction test, and sieve analysis were conducted to evaluate the performance of soil mixed with plastic strips. The results showed that the addition of plastic waste improves shear strength, dry density, and load-bearing capacity of soil, while maintaining proper compaction characteristics.

[11] Stiffness Degradation of Expansive Soil Stabilized with Construction and Demolition Waste under Wetting–Drying Cycles (2025) by **Haodong Xu and Chao Huang** – studied the long-term performance of expansive soil stabilized with construction and demolition waste (CDW), especially under repeated wetting and drying conditions, which are common in real field situations. The authors explained that in humid and hot climates, subgrade soils often lose their strength over time due to moisture changes, so it is important to understand how stabilized soil behaves under such conditions. In this study, different percentages of CDW were mixed with expansive soil, and laboratory tests were carried out to find the optimum percentage, which was found to be around 40%. Various tests such as swelling tests, compaction tests, and California Bearing Ratio (CBR) were conducted to evaluate the physical and engineering properties of the stabilized soil. The study also included advanced testing like cyclic triaxial loading to determine the resilient modulus (Mr), which indicates the stiffness of soil under repeated loading conditions.

[12] A Technical Note on Unconfined Compressive Strength (UCS) of Black Cotton Soil Reinforced with Hydrophobically-Treated Bamboo Fibres (2025) by Sumit Kumar, Brahmdeo Yadav, and Rohit Raj – investigated the effectiveness of hydrophobically-treated bamboo fibres in enhancing the strength characteristics of black cotton soil. The authors emphasized that expansive soils like black cotton soil pose significant challenges due to their high swelling and shrinkage behavior, which leads to structural instability. While conventional stabilization methods such as lime and cement improve strength, they are associated with environmental concerns and higher costs. Therefore, the study explored bamboo fibres as a sustainable and eco-friendly alternative, with special treatment applied to overcome their natural hydrophilic behavior. In this study, black cotton soil samples were mixed with varying percentages of treated bamboo fibres (1%, 1.5%, 2%, and 2.5%) and tested for Unconfined Compressive Strength (UCS) at different curing periods (0, 14, and 28 days). The results demonstrated that the inclusion of hydrophobically-treated bamboo fibres significantly improved UCS values. At 0 days of curing, a 65% increase in UCS was observed with 1% fibre content.

[13] Performance of Expansive Soil Stabilized with Bamboo Charcoal, Quarry Dust, and Lime for Use as Road Subgrade Material (2024) by Essizewa Essowedeou Agate, Nyomboi Timothy, Ambassah O. Nathaniel, and Ines Ngassam – investigated a triphasic stabilization approach for improving the engineering properties of black cotton soil using bamboo charcoal, quarry dust, and lime. The authors emphasized that expansive soils exhibit high plasticity, swelling potential, and low strength, which make them unsuitable for road subgrade applications without treatment. The study aimed to develop a sustainable and cost-effective stabilization technique by incorporating natural and industrial by-products. The experimental program was conducted in three stages. Initially, bamboo charcoal was added in varying proportions (5% to 35%), which resulted in a gradual reduction in plasticity index and swell characteristics, with improvement in California Bearing Ratio (CBR) up to an optimum value at 20% bamboo charcoal. In the second phase, quarry dust was introduced (4% to 24%) along with the optimum bamboo charcoal content, which further enhanced the CBR value to about 7.7% at 12% quarry dust, although the plasticity index showed a non-linear variation.

[14] Review of Subgrade Soil Stabilised with Natural and Synthetic Fibres (2024) by J. M. Nathen, A. K. Arshad, N. M. Rais, E. Shaffie, F. Ismail, N. A. Kamaluddin, and A. Z. A. Malek – presented a comprehensive review on the effectiveness of natural and synthetic fibers in improving the engineering properties of subgrade soils. The authors emphasized that subgrade soil plays a crucial role in pavement performance by providing support to overlying layers, and its failure often leads to pavement distress due to settlement and reduced load-bearing capacity. The study discussed various soil stabilization techniques, including thermal, electrical, mechanical, and chemical methods, while highlighting that chemical stabilization using cement and lime is the most common practice. However, the authors pointed out that conventional stabilizers like cement and lime have become increasingly expensive and environmentally unsustainable, prompting the need for alternative solutions such as fiber reinforcement. The review compared natural fibers (such as bamboo, coir, jute) and synthetic fibers (such as polypropylene and polyester) in terms of their effectiveness in improving soil properties.

[15] Soil Stabilization of Subgrade Level Using Ceramic Powder (2024) by **Dr. S. Thenmozhi and A. Mohan** – studied the stabilization of expansive soil using ceramic powder as a stabilizing material to improve subgrade performance for pavement construction. The authors explained that expansive soils undergo volume changes due to variation in moisture content, which leads to pavement distortion and increases both thickness and construction cost. The study focused on mixing ceramic powder with soil in different proportions such as 10%, 20%, and 30% to evaluate improvements in engineering properties. Laboratory tests showed that the plasticity index decreased from 22% to 18%, indicating reduced swelling behavior, while the California Bearing Ratio (CBR) increased from 1.7% to 2.2% at 30% replacement, showing improvement in load-bearing capacity. The optimum mix was found to be 70% soil and 30% ceramic powder. The study also included pavement design using IRC guidelines, and it was observed that the stabilized soil resulted in a reduction of pavement thickness by about 41% to 45% depending on traffic conditions.

[16] Optimization of Physical and Strength Performance of Cellulose-Based Fiber Additives Stabilized Expansive Soil (2024) by Frehaileab Admasu Gidebo, Naoki Kinoshita, and Hideaki Yasuhara – investigated the effectiveness of cellulose-based fiber additives such as bamboo fiber, rice husk fiber, and wheat straw fiber in improving the engineering properties of expansive soils. The authors highlighted that expansive soils are highly problematic due to their susceptibility to moisture-induced swelling and shrinkage, leading to instability in civil engineering structures. The study aimed to optimize the physical and mechanical properties of soil using different fiber types, sizes (75 µm, 150 µm, and 300 µm), and dosages (5%, 10%, and 15%) through an advanced statistical optimization technique using the Taguchi method and Analysis of Variance (ANOVA). The experimental investigation included evaluation of Atterberg limits, Plasticity Index (PI), Free Swell Ratio (FSR), Linear Shrinkage (LS), and Unconfined Compressive Strength (UCS).

[17] Optimization of Mixtures of Soil, Construction and Demolition Waste, and Steel Slag Using the Simplex-Extreme Vertices Method (2024) by **José Roberto Fernandes Galindo, Heraldo Nunes Pitanga, Leonardo Gonçalves Pedroti, Taciano Oliveira da Silva, Gustavo Henrique Nalon, Gustavo Emilio Soares de Lima, and Beatryz Cardoso Mendes** – studied the stabilization of soil using a combination of construction and demolition waste (CDW) and steel slag with the aim of improving strength and performance of pavement layers through an optimized mix design approach. The authors explained that in many geotechnical projects, natural soil does not meet required strength and durability criteria, so stabilization using waste materials can provide a sustainable and effective solution. In this study, advanced optimization techniques like simplex-extreme vertices method and desirability function were used to determine the best proportions of soil, CDW, and steel slag for maximum performance. Laboratory tests were conducted to evaluate important properties such as Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR), and regression models were developed which showed high accuracy in predicting results.

[18] Comparative Analysis of Volume Change Behavior of Expansive Road Subgrades Stabilized with Waste Paper Sludge (2024) by Muhammed Tanyıldızı, İslam Gökalp, Abdülhakim Zeybek, and Volkan Emre Uz – studied the effect of waste paper sludge (WPS) on the volume change behavior of expansive soils used in road subgrades, focusing on sustainable and eco-friendly stabilization methods. The authors explained that expansive soils are highly problematic because they swell when wet and shrink when dry, which causes serious damage to pavements and structures, leading to high maintenance costs worldwide. The study investigated the use of waste paper sludge, which is a by-product of paper recycling industries, as an alternative stabilizing material to reduce swelling and shrinkage behavior of soils. Laboratory tests were conducted by adding different percentages of waste paper sludge such as 3%, 6%, 9%, 12%, and 15% to expansive soils. Various tests including Atterberg limits, swelling tests, shrinkage tests, compaction tests, and consolidation tests were performed to evaluate the changes in soil properties.

[19] Soil Stabilization Using Construction and Demolition Waste for Pavement Construction (2023) by Aayushi Gupta, Anshika Singh, Sachin Kumar, Shalu Shukla, and Yash Kumar Keshari – studied the effect of construction and demolition waste (CDW) on soil properties for pavement construction with the aim of improving subgrade performance in an economical and sustainable way. The authors explained that due to rapid urbanization and population growth, there is an increasing demand for better road infrastructure, and the performance of roads largely depends on the strength of subgrade soil. Many natural soils do not meet the required standards for pavement construction, so stabilization is necessary to improve their engineering properties. In this study, laboratory tests such as water content, specific gravity, Atterberg limits, sieve analysis, compaction test, and California Bearing Ratio (CBR) test were conducted by mixing soil with different percentages of CDW like 10%, 20%, 30%, and 40%. The results showed that the Maximum Dry Density (MDD) decreased from 1.88 g/cc to 1.767 g/cc with increasing CDW content, while the Optimum Moisture Content (OMC) slightly decreased from 11.95% to 11.08%.

[20] Use of Recycled Construction and Demolition Waste Material in Soil Stabilization (2023) by **Rajiv Pazare, Gaurav Yede, Ayush Lonare, Aniket Khawshi, Nayna Charmode, and Ashutosh Ingle** – studied the use of recycled construction and demolition (C&D) waste for stabilization of black cotton soil with a focus on economical and environmentally friendly solutions. The authors explained that due to rapid growth of the construction industry, a very large amount of C&D waste is generated in India, estimated to be more than 150 million tonnes annually, while the recycling capacity is very low, creating serious disposal problems. The study aimed to utilize this waste material effectively for improving weak soil properties. The researchers conducted laboratory tests by mixing recycled C&D waste with black cotton soil in different proportions such as 15%, 20%, and 25% to evaluate changes in engineering properties. The results showed that the California Bearing Ratio (CBR) value increased significantly from about 7.77% to 12.36%, indicating improvement in soil strength and load-bearing capacity. It was also observed that the Maximum Dry Density (MDD) decreased from 2.104 g/cm³ to 1.86 g/cm³, while the Optimum Moisture Content

(OMC) increased from 13.15% to 18.04% with increasing percentage of C&D waste, showing changes in compaction characteristics.

[21] Soil Stabilization of Black Cotton Soil Using Lime and Wood Ash (2022) by Iqbal Javeed Lone and Pardeep Singh Joia – studied the stabilization of black cotton soil using lime and wood ash as cost-effective and locally available stabilizing materials. The authors emphasized that black cotton soil, due to its high plasticity, swelling-shrinkage behavior, and low shear strength, is unsuitable for construction without proper stabilization. In this study, lime and wood ash were added separately as well as in combination in different proportions to evaluate their effects on soil properties. Lime was varied from 2% to 8%, and wood ash from 8% to 24%, and a total of 24 different soil samples were tested. The experimental investigation included Atterberg limits, Standard Proctor test, Unconfined Compressive Strength (UCS), and California Bearing Ratio (CBR) tests conducted as per Indian Standards. The results showed that the addition of lime increased the Optimum Moisture Content (OMC) while decreasing the Maximum Dry Density (MDD). When lime and wood ash were used together, OMC slightly increased and MDD showed a marginal reduction. However, the strength parameters improved significantly.

[22] Experimental Study of Black Cotton Soil Stabilization with Natural Lime and Pozzolans in Pavement Subgrade Construction (2022) by Zihong Yin, Raymond Leiren Lekalpure, and Kevin Maraka Ndiema – investigated the stabilization of black cotton soil using natural lime, volcanic ash (VA), and their combined application for improving subgrade performance in pavement construction. The authors emphasized that black cotton soil is highly expansive due to the presence of clay minerals such as montmorillonite, leading to excessive swelling, shrinkage, low bearing capacity, and poor shear strength, which make it unsuitable for construction without treatment. The study conducted laboratory tests including Atterberg limits, Proctor compaction test, swell percentage, and California Bearing Ratio (CBR) to evaluate the effectiveness of stabilizers. The results revealed that the addition of volcanic ash and lime significantly improved the engineering properties of black cotton soil. It was observed that stabilization with a combination of 3% lime and 20% volcanic ash provided superior performance compared to individual use. This combination increased the natural CBR value by approximately 10.76 times, reduced plasticity index by about 29%, and decreased swell percentage by nearly 88%. The study also indicated that stabilized soil met the required standards for subgrade materials, eliminating the need for costly soil replacement methods

[23] The Use of Fine Portions from Construction and Demolition Waste for Expansive Soil Stabilization: A Review (2022) by Mgboawaji Claude Ujile and Samuel Jonah Abbey – studied the use of fine particles of construction and demolition waste (CDW) for stabilization of expansive soils with a focus on sustainable and eco-friendly construction practices. The authors explained that construction and demolition waste is one of the largest waste materials generated worldwide and can be effectively reused as a replacement for natural construction materials. The study reviewed various research works on the use of CDW in soil stabilization and highlighted that materials like crushed brick and recycled aggregates have good chemical and mechanical properties which help in improving soil strength. The paper discussed that fine portions of CDW act as filler materials in expansive soils, which reduces voids and improves the density and stability of soil. It was observed that the addition of CDW reduces the swelling potential of expansive soils and increases compressive strength, making the soil suitable for pavement and subgrade applications. The authors also highlighted that the use of CDW can reduce the dependence on cement and other traditional stabilizers, which helps in reducing carbon emissions and environmental impact.

[24] Review on Effects of Construction and Demolished Waste on Strength Parameters of Black Cotton Soil (2022) by **Shreyash Dilip Makode, Pawan Sanjay Mokle, Samrat Lalasaheb Patil, Yuvraj Dhansingh Badhiye, and Prof. Gayatri Chandrakant Sherkar** – studied the use of construction and demolition waste (C&D waste) for improving the strength properties of black cotton soil. The authors explained that the construction industry is one of the largest sectors in India and generates a large amount of waste due to continuous construction and demolition activities. This waste, if not properly managed, creates environmental problems, but it can be effectively used as a stabilizing material for weak soils. The study focused on black cotton soil, which is highly problematic due to its low bearing capacity, high compressibility, and high swelling and shrinkage characteristics. The authors discussed that during the rainy season, black cotton soil expands and causes heaving of structures, while in summer it shrinks and forms cracks, leading to structural damage. The research suggested the use of demolition waste particles, especially coarser fractions between 2.36 mm and 4.75 mm, to improve soil properties. Laboratory tests were recommended by mixing different percentages of waste such as 0%, 10%, 15%, 20%, and 25% with soil to determine the optimum percentage for maximum strength improvement. The study highlighted that soil stabilization is a better and more economical solution compared to complete replacement of weak soil, especially for low-cost construction in rural areas. It was also observed that the use of construction and demolition waste improves shear strength, bearing capacity, and overall performance of soil.

[25] Stabilization of Clayey Soil with Construction Demolition Waste (2022) by **I. Vinod Kumar Reddy, R. Bhaskar, M. Prabhu, S. Benhin, A. Sai Kumar, and Dr. D. Venkateswarlu** – studied the stabilization of clayey soil using construction and demolition (C&D) waste with the aim of improving soil strength and subgrade characteristics for construction purposes. The authors explained that clayey soil has high swelling behavior and poor strength, which leads to problems like settlement and failure of roads and foundations, so stabilization is necessary to improve its engineering properties. The study focused on using C&D waste as a stabilizing material and conducted laboratory tests by mixing different percentages of waste with soil to evaluate changes in properties such as Optimum Moisture Content (OMC), Maximum Dry Density (MDD), Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), and Atterberg limits. The results showed that with the increase in C&D waste content, the strength of soil improved, and optimum results were obtained at around 8% addition of C&D waste. It was observed that UCS and CBR values increased, indicating improvement in load-bearing capacity, while liquid limit decreased slightly and plastic limit remained almost unchanged.

[26] Improvement of Soil using Construction and Demolition Waste for Pavement Application (2022) by A. R. Prajapati, A. U. Shah, P. H. Jain, and H. M. Rangwala – studied the use of construction and demolition waste (C&DW) for improving soil properties for pavement applications. The authors explained that India is facing a serious problem due to the large quantity of construction and demolition waste generated every year, which is around 150 million tonnes, while the recycling capacity is very low. Due to this, there is an urgent need to find effective methods for reuse and recycling of this waste material. The study focused on using C&DW as a stabilizing material by mixing it with soil in different proportions for subgrade applications. The materials used in C&DW include concrete, bricks, wood, metals, and other non-biodegradable materials, which have good engineering properties and can be reused in construction. The authors carried out laboratory tests such as Standard Proctor Compaction Test and California Bearing Ratio (CBR) Test on soil mixed with different percentages of C&DW like 0%, 25%, 50%, and 75%.

[27] Use of Construction and Demolition Waste for Ground Improvement (2021) by Pratik Patil, Prakash Panda, Mehul Neman, Sangram Mhetre, and Bhavik Sankhe – studied the use of construction and demolition waste (CDW) for improving the strength of weak soils like black cotton soil in ground improvement applications. The authors explained that the construction industry is one of the largest contributors to the Indian economy, and due to continuous construction and demolition activities, a large amount of waste is generated every year. This waste, if not properly utilized, creates environmental and disposal problems. Therefore, the study focused on using demolition waste obtained from building slabs as a stabilizing material for soil improvement. The researchers used coarser fractions of CDW, particularly particles between 2.36 mm and 4.75 mm, to improve the properties of black cotton soil. Laboratory tests such as triaxial tests were conducted on soil mixed with different proportions of construction waste like 0%, 5%, 10%, 15%, and 20% to determine the optimum percentage for maximum strength gain. The results showed that the addition of CDW significantly improved the strength characteristics of the soil, and an optimum percentage of waste was identified where maximum improvement was achieved.

[28] Soil Stabilization by Construction and Demolition Waste: A Review (2021) by Harkamal Singh, Ahmed Ziya Siddiqui, Betina Akham, Evodie Ngoie Kikumi, Shuhabbhudin Qazi, and Muhammad Yusuf Sharifi – studied the use of construction and demolition waste (CDW) for soil stabilization and its importance in sustainable development. The authors explained that a large amount of construction and demolition waste is generated during construction and demolition activities, and most of this waste is not properly utilized, which creates environmental problems such as pollution and land degradation. The study focused on finding effective ways to reuse this waste in civil engineering applications, especially for soil stabilization. The authors highlighted that soil plays a very important role in supporting structures like buildings, roads, bridges, and dams, and if the soil is weak, it can lead to problems such as cracking, settlement, and structural failure. Therefore, soil stabilization is necessary to improve the engineering properties of soil. The paper described soil stabilization as the process of improving the physical and chemical properties of soil to make it suitable for construction. It also discussed that soil has been used in construction since ancient times and civilizations like Romans and Chinese used different methods to improve soil properties, while modern soil stabilization techniques started in India around the 1970s due to the shortage of good quality construction materials.

[29] A Review Study on Partial Use of Building Demolition Waste as Lime Treated Base Course in Bituminous Road (2020) by Bipul Dhakal and Avni Chopra – studied the use of building demolition waste combined with lime as a base course material in bituminous roads with the aim of improving strength and reducing the use of natural aggregates. The authors explained that due to rapid urbanization and construction activities, a large amount of demolition waste is generated, and although some portion is recycled, a significant amount is still disposed in landfills, causing environmental and traffic problems. The study focused on utilizing demolition waste by treating it with lime to enhance its engineering properties and make it suitable for road base layers. Laboratory tests such as dry density, specific gravity, abrasion value, impact value, and crushing value were conducted on demolition waste aggregates, and after lime treatment, important parameters like California Bearing Ratio (CBR) and resilient modulus were evaluated.

[30] Soil Improvement by Fine Fraction Residue from Recycling Construction and Demolition Waste (2019) by **B. J. S. Varaprasad, Joga Jayaprakash Reddy, Talluri Rajesh, Y. Yaswanth Kumar, and K. Ram Mohan Reddy** – studied the use of fine fraction residue obtained from recycled construction and demolition waste (CDW) for stabilization of expansive soils with the aim of improving strength and reducing swelling characteristics. The authors explained that rapid urbanization has increased construction activities, leading to large quantities of waste, which creates environmental problems if not reused properly. The study focused on utilizing fine fractions of CDW, which are usually not effectively used, as a stabilizing material for expansive soils. Laboratory tests were conducted by mixing CDW with soil in different proportions such as 5%, 10%, 15%, 20%, and 25%, and tests like Atterberg limits, Unconfined Compressive Strength (UCS), Free Swell Index (FSI), swell pressure, and California Bearing Ratio (CBR) were performed.

[31] Stabilisation of Subgrade Soil Using Demolished Concrete Aggregate (2018) by **Amrutha Abraham, Shamna Mol S., Praveen D. Dethan, and Kavitha S.** – studied the stabilization of subgrade soil using demolished concrete aggregate with the aim of improving strength and performance of pavement structures. The authors explained that the long-term performance of roads depends mainly on the stability of subgrade soil, and weak soils like red soil often cause failures in pavements due to low strength, poor water holding capacity, and high swelling behavior. The study focused on using construction and demolition waste, particularly demolished concrete aggregates, as a stabilizing material instead of traditional materials like lime and cement, which are costly and may harm the environment. Laboratory tests such as Atterberg limits, shrinkage limit, compaction test, and California Bearing Ratio (CBR) test were conducted on soil mixed with different percentages of demolished concrete aggregates to evaluate the improvement in soil properties. The results showed that the addition of demolished concrete aggregate improves shear strength, bearing capacity, and overall stability of the soil, making it more suitable for subgrade applications. The study also highlighted that improved CBR values can help in reducing pavement thickness, which leads to cost savings in road construction.

[32] Stabilization of Expansive Soils Using Construction and Demolition Waste (2018) by **Vivek S., Parimal Kumar, Vivek Shukla, Kiran Markal, and Mallikarjun** – studied the stabilization of black cotton soil using construction and demolition (C&D) waste with the aim of improving soil strength and reducing swelling behavior. The authors explained that black cotton soil contains montmorillonite minerals which cause high swelling and shrinkage due to changes in moisture content, leading to serious problems in construction such as cracks, settlement, and structural failure. The study focused on using C&D waste materials like concrete debris, plaster, and brick waste as stabilizers for improving soil properties. Laboratory tests such as Standard Proctor Test and Direct Shear Test were conducted by mixing different percentages of C&D waste with soil, and it was found that an optimum mix of around 10% C&D waste provided the best results. The results showed that the addition of C&D waste significantly improved cohesion, angle of internal friction, and safe bearing capacity of soil, while also reducing swelling characteristics.

[33] Soil Stabilization using Demolished Concrete – A Review (2018) by **Ashutosh Kumar and Prof. Pankaj Rathod** – studied the use of demolished concrete waste as a stabilizing material for improving the properties of weak soils, especially clayey and black cotton soils. The authors explained that due to rapid construction activities, a large amount of construction and demolition waste is generated worldwide, which creates disposal problems and environmental issues. Therefore, the study focused on the reuse of demolished concrete waste, particularly the fine particles obtained after crushing, as a low-cost and effective soil stabilizer. The paper discussed that soil stabilization is necessary to improve bearing capacity, strength, and durability of weak soils used in road construction. Various traditional stabilization methods like chemical stabilization, compaction, and soil replacement are available, but they are often costly and sometimes not environmentally friendly.

[34] Stabilization of Debris Material by Using Soil (2017) by **Y. Ravikanth, B. Tejaram, and B. G. Rahul –** studied the use of debris material obtained from construction and demolition activities for stabilization of clayey soil with the aim of improving its engineering properties in a cost-effective way. The authors explained that soil stabilization is an important process used to improve the bearing capacity, strength, and durability of weak soils, especially for construction applications such as roads and foundations. The study highlighted that traditional stabilization methods like chemical stabilization, soil replacement, compaction control, and thermal methods are often expensive and sometimes not efficient for large-scale applications. Therefore, the researchers focused on using debris material, which consists of broken concrete, fine aggregates, coarse aggregates, and cement particles obtained from demolished structures. The paper discussed that when this debris material is mixed with soil, it helps in improving density, strength, and overall performance of the soil. Laboratory tests such as compaction tests, pycnometer test, and density tests were conducted to evaluate the changes in soil properties after mixing debris material.

III. RESEARCH GAP

Based on the review of previous research studies, it is observed that significant work has been carried out on stabilization of black cotton soil using individual materials such as lime, fibers, and industrial waste. However, limited studies have focused on the combined use of lime and bamboo fiber, particularly in determining their optimum proportions for maximum improvement in soil properties. Most of the research has primarily concentrated on either chemical stabilization or mechanical reinforcement separately, with insufficient attention given to their combined interaction effects. Additionally, there is a lack of comprehensive studies evaluating the simultaneous impact on key parameters such as California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS), and shear strength. The behavior of soil beyond optimum fiber content and its influence on performance is also not well explored. Furthermore, limited research has been conducted on pavement design based on improved soil properties and the long-term durability of stabilized soil under varying environmental conditions. Therefore, there is a need for a systematic study focusing on the combined effect of lime and bamboo fiber to develop a cost-effective, sustainable, and efficient soil stabilization technique.

CONCLUSION

From the comprehensive review of previous studies, it can be concluded that stabilization of black cotton soil is essential to improve its engineering properties for construction applications. Various stabilizing agents such as lime, fibers, construction and demolition waste, and industrial by-products have been successfully used to enhance soil strength, reduce plasticity, and improve load-bearing capacity. Lime stabilization is effective in reducing swelling and improving strength through chemical reactions, while fiber reinforcement improves ductility and resistance to cracking. The use of waste materials also contributes to sustainability and cost-effectiveness. However, the combined use of lime and bamboo fiber has not been extensively explored. The findings suggest that an integrated approach combining chemical and mechanical stabilization has the potential to significantly improve soil performance. Therefore, further research is required to optimize the combination of lime and bamboo fiber for practical applications in pavement subgrade construction.

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REFERENCES

[1] Abraham, A., Mol, S. S., Dethan, P. D., and Kavitha, S., "Stabilisation of subgrade soil using demolished concrete aggregate," IRJET, 2018.
[2] Agate, E. E., Timothy, N., Nathaniel, A. O., and Ngassam, I., "Performance of expansive soil stabilized with bamboo charcoal, quarry dust, and lime for use as road subgrade material," SSRG International Journal of Civil Engineering, vol. 11, no. 2, pp. 108–120, 2024.

[3] Barisoglu, E. N., et al., “Utilising construction and demolition waste in soft soil stabilisation: A prediction model,” Transportation Geotechnics, vol. 51, p. 101530, 2025.
[4] Chavan, S. A., et al., “Application of waste plastic material in soil stabilization,” IJRPR, 2025.
[5] Deepak, G. B., et al., “Sustainable stabilization of expansive black cotton soil using recycled PET plastic waste,” International Journal of Environmental Sciences, 2025.
[6] Dhakal, B., and Chopra, A., “Partial use of demolition waste as lime treated base,” IRJET, 2020.
[7] Galindo, J. R. F., et al., “Optimization of mixtures of soil, CDW and steel slag,” Transportation Geotechnics, vol. 48, p. 101361, 2024.
[8] Gidebo, F. A., Kinoshita, N., and Yasuhara, H., “Optimization of physical and strength performance of cellulose-based fiber additives stabilized expansive soil,” Case Studies in Construction Materials, vol. 20, e02851, 2024.
[9] Gupta, A., et al., “Soil stabilization using construction and demolition waste for pavement construction,” IJRASET, vol. 11, no. 9, 2023.
[10] IS: 2720 (Part 2), “Determination of Water Content,” 1973.
[11] IS: 2720 (Part 4), “Grain Size Analysis,” 1975.
[12] IS: 2720 (Part 5), “Determination of Liquid and Plastic Limits,” 1970.
[13] IS: 2720 (Part 13), “Direct Shear Test,” 1972.
[14] Isik, A., “Compressive strength of clay soil stabilized with CDW-based geopolymer,” Bulletin of Engineering Geology and the Environment, vol. 84, 2025.
[15] Kankate, R. P., et al., “Stabilization of black cotton soil using lime and bamboo fiber mixture as a subgrade material,” IJSART, vol. 11, no. 6, 2025.
[16] Kumar, A., and Rathod, P., “Soil stabilization using demolished concrete – A review,” IJSRD, 2018.
[17] Kumar, S., Yadav, B., and Raj, R., “Unconfined compressive strength of black cotton soil reinforced with hydrophobically-treated bamboo fibres,” Discover Sustainability, vol. 6, 2025.
[18] Mahale, S. H., et al., “Rural road pavement design using brick waste,” IJSRET, 2025.
[19] Makode, S. D., et al., “Effects of construction and demolition waste on strength parameters of black cotton soil,” JETIR, vol. 9, no. 11, 2022.
[20] Mishra, G., “Review on stabilization techniques for black cotton soil using various materials,” IRJEdT, vol. 8, no. 9, 2025.
[21] Patil, P., et al., “Use of construction and demolition waste for ground improvement,” IJERT, 2021.
[22] Pazare, R., et al., “Use of recycled construction and demolition waste material in soil stabilization,” IJRASET, vol. 11, no. 5, 2023.
[23] Prajapati, A. R., et al., “Improvement of soil using construction and demolition waste for pavement application,” Indian Geotechnical Conference, 2022.
[24] Ravikanth, Y., et al., “Stabilization of debris material by using soil,” International Journal of Civil Engineering and Technology, vol. 8, no. 4, pp. 2125–2131, 2017.
[25] Reddy, I. V. K., et al., “Stabilization of clayey soil with CDW,” IJMTST, 2022.
[26] Shuvo, B. P., et al., “Geotechnical applications of construction and demolition waste and future prospects,” 2026.
[27] Singh, H., et al., “Soil stabilization by construction and demolition waste: A review,” JETIR, vol. 8, no. 5, 2021.
[28] Thenmozhi, S., and Mohan, A., “Soil stabilization using ceramic powder,” Nanotechnology Perceptions, vol. 20, 2024.
[29] Tanyıldızı, M., and Gökalp, İ., “Stabilization of expansive road subgrades with waste paper sludge,” Transportation Geotechnics, vol. 52, p. 101552, 2025.
[30] Tanyıldızı, M., et al., “Comparative analysis of volume change behavior of expansive road subgrades stabilized with waste paper sludge,” Scientific Reports, 2024.
[31] Ujile, M. C., and Abbey, S. J., “Use of fine portions from construction and demolition waste for expansive soil stabilization: A review,” Frontiers of Structural and Civil Engineering, vol. 16, pp. 803–816, 2022.
[32] Varaprasad, B. J. S., et al., “Soil improvement by fine fraction residue from CDW,” International Journal of Scientific & Technology Research, vol. 8, no. 10, 2019.
[33] Vivek, S., et al., “Stabilization of expansive soils using construction and demolition waste,” IRJET, 2018.
[34] Xu, H., and Huang, C., “Stiffness degradation of expansive soil stabilized with CDW under wetting–drying cycles,” Scientific Reports, 2025.
[35] Bizualem, L., and Gidebo, F. A., “Performance assessment of bamboo and sisal fiber reinforcement in red ash stabilized expansive black cotton soil,” Results in Engineering, vol. 29, 2026.