A Comprehensive Review on Stabilization of Black Cotton Soil Using Shredded Waste Tyre Rubber and GGBS

Mr. Vinay Kumar Hungund, Jayaram, S Aravind, D Ashritha, Dadapeer
Assistant Professor, Department of Civil Engineering, Ballari Institute of Technology and Managemant, Ballari, Karnataka, India
U.G. Student, Department of Civil Engineering, Ballari Institute of Technology and Managemant, Ballari, Karnataka, India
U.G. Student, Department of Civil Engineering, Ballari Institute of Technology and Managemant, Ballari, Karnataka, India
U.G. Student, Department of Civil Engineering, Ballari Institute of Technology and Managemant, Ballari, Karnataka, India
U.G. Student, Department of Civil Engineering, Ballari Institute of Technology and Managemant, Ballari, Karnataka, India

How to Cite this Article:
Dadapeer, , Ashritha, D., Aravind, S. & Jayaram, (2026). A Comprehensive Review on Stabilization of Black Cotton Soil Using Shredded Waste Tyre Rubber and GGBS. International Journal of Creative and Open Research in Engineering and Management, <i>02</i>(05).
https://doi.org/10.55041/ijcope.v2i5.287

https://doi.org/10.55041/ijcope.v2i5.287

ABSTRACT: Black cotton soil (BCS) is an expansive soil with high swelling and shrinkage characteristics, causing significant challenges in construction. This study reviews various stabilization techniques using chemical stabilizers and sustainable materials such as shredded waste tyre rubber and Ground Granulated Blast Furnace Slag (GGBS). The effects on engineering properties like Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), and compaction are analyzed. Results indicate that cement and lime improve strength, while rubber enhances flexibility. Hybrid stabilization provides superior performance, with optimum rubber content around 5%. The study highlights sustainable, cost-effective solutions for improving black cotton soil in engineering applications.

KEYWORDS: Black cotton soil, stabilization, shredded rubber, GGBS, CBR and UCS

I. INTRODUCTION

Black cotton soil (BCS) is one of the most problematic soils encountered in geotechnical engineering due to its highly expansive nature and poor engineering properties. It is widely found in tropical and semi-arid regions, especially in India, and is formed from the weathering of basaltic rocks. The presence of montmorillonite clay mineral makes it highly sensitive to moisture changes, leading to significant swelling during wet conditions and shrinkage during dry conditions. These volume changes cause serious issues such as cracking of pavements, differential settlement, and structural instability.

Due to its high plasticity, low shear strength, and poor load-bearing capacity, black cotton soil is unsuitable for construction without proper treatment. To overcome these challenges, soil stabilization techniques are used to improve its engineering properties. Stabilization involves modifying the soil using mechanical or chemical methods to enhance strength, durability, and performance.

Chemical stabilizers such as cement and lime are commonly used, as they form cementitious compounds that improve soil strength and reduce plasticity. Recently, sustainable materials like shredded waste tyre rubber and Ground Granulated Blast Furnace Slag (GGBS) have gained attention for their environmental and economic benefits, offering an effective solution for soil improvement.

II. LITERATURE SURVEY

Black cotton soil (BCS) is widely known for its poor engineering properties, including high swelling and shrinkage, low strength, and inadequate load-bearing capacity. To address these issues, several researchers have explored different stabilization techniques using both conventional and alternative materials.

Traditional stabilizers such as cement and lime have been extensively used due to their effectiveness in improving soil strength and reducing plasticity. Cement stabilization enhances the formation of cementitious compounds like calcium silicate hydrate (C-S-H), which bind soil particles and increase stiffness. Lime stabilization is effective in reducing swelling and plasticity through chemical reactions with clay minerals. However, these methods can be costly and environmentally unfriendly.

To overcome these limitations, recent studies focus on the use of sustainable materials like shredded waste tyre rubber and industrial by-products. Rubber improves soil flexibility, ductility, and resistance to cracking, although it reduces density due to its lightweight nature. Its effectiveness is highest at an optimum content of around 5%.

Research also indicates that combining rubber with cement provides better results than using them individually. Hybrid stabilization techniques improve both strength and flexibility, making them more suitable for engineering applications.

III. METHODOLOGY

The methodology for stabilizing black cotton soil is based on systematic laboratory experiments aimed at improving its engineering properties using cement and shredded waste tyre rubber. Initially, soil samples are collected from field locations at a depth of about 1 meter to avoid contamination from organic matter. The collected soil is air-dried, pulverized, and passed through a 425 µm sieve to ensure uniformity. Basic properties such as specific gravity, Atterberg limits, and grain size distribution are determined using standard procedures. Cement and shredded rubber are selected as stabilizing materials. Cement is added in proportions of 2% and 4% by weight of soil, while rubber is added in varying percentages such as 0%, 5%, 10%, and 15%. The materials are first mixed thoroughly in dry condition, and then water is added based on the Optimum Moisture Content (OMC).

Compaction characteristics are determined using the Standard Proctor Test to obtain OMC and Maximum Dry Density (MDD). Based on these values, soil samples are prepared and compacted into molds. Cylindrical specimens are prepared for Unconfined Compressive Strength (UCS) tests, while larger molds are used for California Bearing Ratio (CBR) tests.

The prepared samples are cured for periods of 4, 7, and 14 days to study strength development. UCS and CBR tests are then conducted under standard conditions. The results are analyzed through tables and graphs to determine the effect of stabilizers and identify the optimum mix proportion that provides maximum strength and performance improvement.

Table.1: Table.8: CBR Values with Rubber

S.No	Mix Proportion	CBR (2.5mm)	CBR (5mm)
1	BC Soil	3.57	2.91
2	BC + 4% Rubber	5.17	4.77
3	BC + 6% Rubber	7.96	8.49
4	BC + 8% Rubber	9.55	8.89
5	BC + 10% Rubber	8.95	7.83

IV. RESEARCH GAP

The review of literature on black cotton soil stabilization highlights several important research gaps. Most studies focus on the use of individual stabilizers such as cement, lime, fly ash, and agricultural wastes. Although these materials improve properties like Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR), limited attention has been given to hybrid stabilization techniques that combine multiple materials for enhanced performance.

Another significant gap is the insufficient study of shredded waste tyre rubber in combination with other stabilizers like cement and Ground Granulated Blast Furnace Slag (GGBS). While rubber improves ductility and flexibility, its combined effect with other materials is not fully explored, especially in terms of optimal mix proportions and long-term behavior.

Additionally, most research is based on short-term laboratory experiments, typically up to 28 days of curing. There is a lack of long-term studies evaluating durability under field conditions, including environmental factors such as wetting–drying cycles and repeated loading.

The absence of standardized mix design procedures and limited field validation make it difficult to apply these findings practically. These gaps emphasize the need for comprehensive and long-term research.

V. DATA SOURCE

The data used in this review is obtained from reliable secondary sources, including research papers, journals, and experimental studies on black cotton soil stabilization. These sources provide detailed information on soil properties, stabilization techniques, and performance evaluation using both conventional materials and sustainable alternatives.

A key source is the study by Ghatge and Rakaraddi (2014), which investigates the use of shredded waste tyre rubber combined with cement. It provides experimental data on Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), compaction characteristics, and curing effects for different mix proportions.

Another important source is the International Journal for Multidisciplinary Research (2023), which examines the effect of varying rubber content on soil behavior. It includes data on Optimum Moisture Content (OMC), Maximum Dry Density (MDD), and CBR values, helping identify optimum stabilizer content.

Additional data is collected from studies on cement, lime, fly ash, and Ground Granulated Blast Furnace Slag (GGBS). Standard testing procedures such as IS 2720 ensure consistency and accuracy. Overall, these sources provide a comprehensive dataset for evaluating stabilization methods.

VI. MATERIALS USED FOR STABILIZATION

The stabilization of black cotton soil involves the use of various materials to improve its strength, bearing capacity, and resistance to swelling and shrinkage. The primary materials used in the reviewed studies include black cotton soil, cement, shredded waste tyre rubber, and Ground Granulated Blast Furnace Slag (GGBS).

Black cotton soil is a highly expansive clay soil characterized by high plasticity, low strength, and significant volume changes due to moisture variation. It is generally collected from natural deposits, air-dried, and sieved to obtain uniform particles for laboratory testing. Due to its poor engineering properties, stabilization is necessary before its use in construction.

Cement is widely used as a chemical stabilizer due to its ability to form cementitious compounds through hydration reactions. These compounds bind soil particles together, improving strength, stiffness, and durability. In most studies, cement is used in small proportions ranging from 2% to 4% by weight of soil.

Shredded waste tyre rubber is an innovative and eco-friendly material used for soil reinforcement. It is obtained from discarded tyres and processed into small pieces. Rubber improves ductility, flexibility, and resistance to cracking. However, due to its low specific gravity, it reduces soil density, and its optimum content is generally around 5%.

GGBS is an industrial by-product with cementitious and pozzolanic properties. It improves long-term strength, reduces plasticity, and enhances durability. When combined with cement and rubber, it provides a balanced improvement in soil properties, making the stabilized soil suitable for engineering applications.

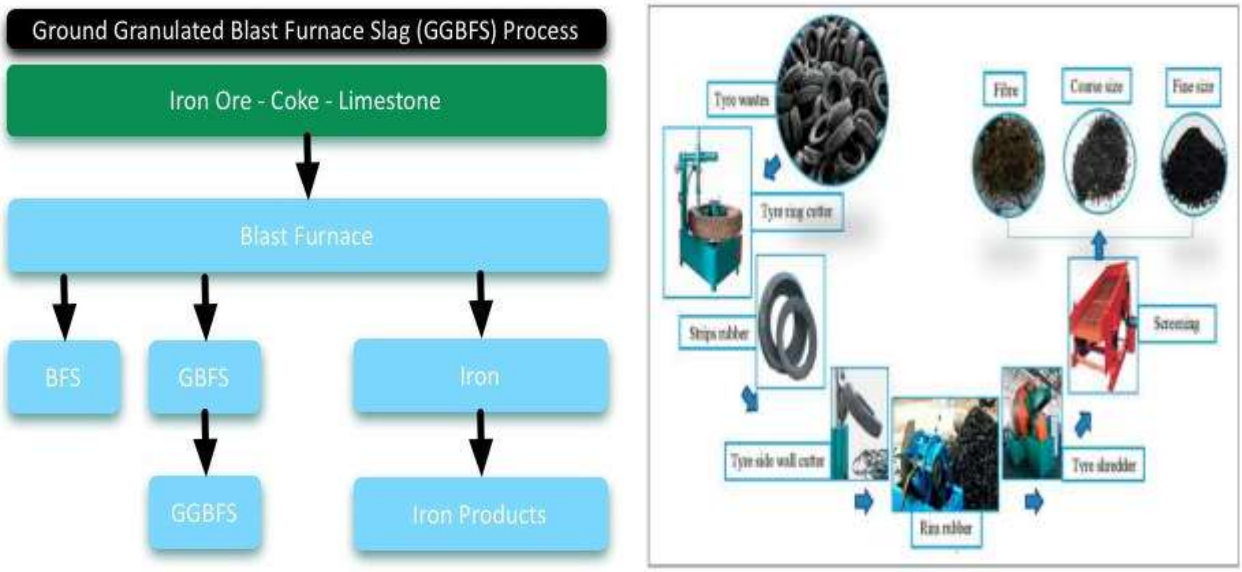

Fig.2: GGBFS and Waste Tyre Rubber used in soil stabilization

VII. ENVIRONMENTAL & ECONOMIC BENEFITS

The use of waste tyre rubber and industrial by-products such as Ground Granulated Blast Furnace Slag (GGBS) in the stabilization of black cotton soil offers significant environmental and economic advantages. One of the major environmental benefits is the effective utilization of waste tyres, which are non-biodegradable and pose serious disposal problems. By converting these tyres into shredded rubber for soil stabilization, landfill waste is reduced and environmental pollution is minimized.

The use of such recycled materials promotes sustainable construction practices by reducing dependency on natural resources like aggregates and conventional stabilizers. Additionally, replacing a portion of cement with materials like GGBS helps lower carbon emissions, as cement production is a major contributor to greenhouse gases. This contributes to a reduction in the overall carbon footprint of construction projects.
From an economic perspective, waste tyre rubber is a low-cost and readily available material, which helps reduce the overall cost of stabilization. Improved soil strength, indicated by higher California Bearing Ratio (CBR) values, leads to a reduction in pavement thickness. This results in significant savings in construction materials and transportation costs.
Stabilized soil exhibits improved durability, reduced cracking, and better resistance to swelling and shrinkage. This decreases maintenance and repair costs over the lifespan of the structure. The lightweight nature of rubber also reduces handling and transportation efforts.
The combined use of waste tyre rubber and GGBS provides a cost-effective, eco-friendly, and sustainable solution for improving the performance of black cotton soil in engineering applications.

Fig.1: Environmental and Economic benefits

VIII. CRITICAL DISCUSSION

The reviewed studies highlight that Traditional Stabilizers such as cement, lime, and GGBS significantly improve the strength and durability of black cotton soil. However, a major limitation of these materials is that they tend to make the soil brittle, which can lead to cracking under dynamic loading conditions. On the other hand, shredded waste tyre rubber enhances flexibility, ductility, and resistance to deformation, but it does not contribute to chemical bonding or significant strength improvement when used alone.

A key observation is that hybrid stabilization techniques provide superior performance compared to individual stabilizers. The combination of cement or GGBS with rubber creates a balanced system where strength is improved through chemical reactions, while flexibility is enhanced through reinforcement. This makes the stabilized soil more suitable for practical applications such as road subgrades.

Despite these advantages, several limitations exist. Most studies are limited to laboratory conditions and short curing periods, with insufficient long-term field data. Additionally, the lack of standardized mix design procedures and variability in soil properties make it difficult to generalize results. Therefore, further research is required to develop optimized mix designs, conduct field validation, and evaluate long-term performance.

Table.2: Recommended Optimum Stabilization Mix

Material	**Recommended %**	**Role in Combination**
Cement (OPC 53)	2–6%	Primary strength via hydration; bonds particles
Shredded Rubber	~5%	Reduces brittleness; improves ductility & flexibility
GGBS	10–20%	Long-term strength; pozzolanic; eco-friendly cement replacement

IX. CONCLUSION

The review of studies on black cotton soil stabilization indicates that untreated soil possesses poor engineering properties such as high plasticity, excessive swelling and shrinkage, low shear strength, and very low bearing capacity. These characteristics make it unsuitable for construction without proper treatment. The use of traditional stabilizers like cement and lime significantly improves strength and reduces plasticity through hydration and pozzolanic reactions. However, their high cost and environmental impact encourage the use of alternative materials.

Sustainable materials such as Ground Granulated Blast Furnace Slag (GGBS) and shredded waste tyre rubber have shown promising results in improving soil properties. GGBS enhances strength and durability while reducing carbon emissions, whereas rubber improves flexibility, ductility, and resistance to cracking. The studies reveal that the optimum rubber content is around 5%, beyond which strength decreases due to increased voids.

The combined use of cement, GGBS, and rubber provides a balanced improvement in strength, flexibility, and durability. This results in increased UCS and CBR values, reduced pavement thickness, and lower construction costs. Overall, this approach offers an effective, economical, and environmentally sustainable solution for stabilizing black cotton soil.

X. REFERENCES

1. Ghatge, S. A., & Rakaraddi, P. G. (2014). *Stabilization of black cotton soil and shedi soil using shredded rubber tyre chips*. International Journal of Research in Engineering and Technology, 3(12), 23–29.

2. International Journal for Multidisciplinary Research (2023). *Stabilization of soil using shredded rubber tyre*. IJFMR, 5(4), 1–6.

3. Singh, B., & Garg, R. (2018). *Use of industrial waste in soil stabilization: A review*. International Journal of Civil Engineering Research, 9(2), 145–152.

4. Sharma, R. K., & Sivapullaiah, P. V. (2016). *Ground granulated blast furnace slag amended soil stabilization*. Journal of Materials in Civil Engineering, 28(5), 04016010.

5. Ingles, O. G., & Metcalf, J. B. (1972). *Soil Stabilization: Principles and Practice*. Butterworths, London.

6. Sherwood, P. (1993). *Soil Stabilization with Cement and Lime*. Transport Research Laboratory, UK.

7. IRC:37 (2018). *Guidelines for the Design of Flexible Pavements*. Indian Roads Congress, New Delhi.

8. IS 2720 (Various Parts). *Methods of Test for Soils*. Bureau of Indian Standards, New Delhi.

9. IS 4332 (Part 1–5). *Methods of Test for Stabilized Soils*. Bureau of Indian Standards, New Delhi.

10. Yadav, R. K., & Tiwari, S. K. (2017). *Effect of waste rubber tyres on engineering properties of soil*. International Journal of Engineering Research & Technology, 6(5), 223–227.

11. Kumar, A., & Singh, D. (2019). *Stabilization of black cotton soil using industrial waste materials*. International Journal of Innovative Technology and Exploring Engineering, 8(9), 1021–1025.

12. Patel, A. (2012). *Geotechnical Engineering*. McGraw Hill Education, New Delhi.

13. Arora, K. R. (2010). *Soil Mechanics and Foundation Engineering*. Standard Publishers, New Delhi.

14. Sabat, A. K., & Nanda, R. P. (2011). *Effect of marble dust on strength and durability of rice husk ash stabilized expansive soil*. International Journal of Civil and Structural Engineering, 1(4), 939–948.

15. Basha, E. A., Hashim, R., Mahmud, H. B., & Muntohar, A. S. (2005). *Stabilization of residual soil with rice husk ash and cement*. Construction and Building Materials, 19(6), 448–453.

16. Pandian, N. S. (2004). *Fly ash characterization with reference to geotechnical applications*. Journal of Indian Institute of Science, 84, 189–216.