iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** VI **Month of publication:** June 2025

DOI: https://doi.org/10.22214/ijraset.2025.72677

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

Stabilization of Black Cotton Soil Using Shredded Tyre Rubber and Fly Ash

Yogesh Shivaji Kale[1], Dr. Shubhada S. Koranne[2]
[1]*PG Scholar, Department of Civil Engineering, Government College of Engineering Aurangabad, Chhatrapati Sambhajinagar*
[2]*Associate Professor, Department of Civil Engineering, Government College of Engineering Aurangabad, Chhatrapati Sambhajinagar*

Abstract: Within the context of the process of stabilizing black cotton soil (BCS), this study makes an investigation into the utilization of shredded tire rubber (STR) and fly ash (FA). This means that black cotton soil has the potential to cause severe structural damage because of its high swelling and shrinking tendencies. Black cotton soil is infamous for its high swelling and shrinking tendencies. In light of the fact that they are waste products, STR and FA are currently being investigated for their potential to act as stabilizers. Several laboratory studies, such as Atterberg limits, unconfined compressive strength (UCS), California bearing ratio (CBR), and compaction tests, were conducted on soil samples that contained varying levels of STR and FA. These experiments were carried out on soil samples. As a result of the assimilation of these minerals, the strength of the soil is significantly increased, and the flexibility index is significantly decreased. This is the conclusion that can be drawn from the findings. A mixture that contains 10% STR and 20% FA is the optimal combination for boosting the properties of BCS, according to the findings of the study, which indicate that this mixture is essential.
Keywords: Black cotton soil, soil stabilization, shredded tyre rubber, fly ash, mechanical properties, compaction, shear strength.

I. INTRODUCTION

A. Problem Statement

A significant area of the Indian subcontinent is covered by black cotton soil, which presents a number of difficult challenges for the development of infrastructure in the region. In general, the soil is not very strong and has a lower level of stability when it comes to the application of load. In addition to being utilized in the construction of structures, these soils are also utilized in the subgrade of pavement. The fact that black cotton soil has the ability to both expand and contract makes it challenging to use in building. The process of stabilizing the soil is one of the methods that will be implemented in order to enhance the characteristics of soils. Fly ash, mine waste, cement, and lime are only few of the additives that have been utilized in the past with the purpose of stabilizing the soils. In the course of this research, an effort is made to stabilize the soil by utilizing trash from tires. The findings of the study indicate that the engineering features of soil can be enhanced through the incorporation of waste tires, which also provides a solution to the issue of trash disposal during the process.

The globalization of the economy has resulted in an increase in the demand for automobiles and power in a number of countries all over the world. As a consequence of this, a significant amount of fly ash and scrap tyres have been produced, and there are issues that are related with the disposal of these materials in a secure manner. As a result of their typical inherent features, fly ash and tire fibers have the potential to be utilized for the modification of a variety of engineering properties belonging to black cotton soil. When it comes to geotechnical applications, such as the construction of highways, embankments, and backfilling behind retaining structures, there is sufficient room for the usage of fly ash and waste tire materials in large quantities in black cotton soil mixes. The current research work focuses primarily on the strength behavior of black cotton soil that has been treated with fly ash and tire fiber, with regard to the geotechnical performance of these soils.[1]

The black cotton soil, sometimes referred to as BCS, is a type of expansive soil that possesses a high proportion of montmorillonite clay and exhibits significant volume changes as a consequence of variations in the amount of moisture present. It is a challenge for construction projects because of its characteristic of swelling and shrinking, which produces uneven settling, cracks in structures, and failures in roadways. This is because it generates these problems. The BCS is responsible for about twenty percent of India's entire land area, according to studies; hence, it is of the biggest need to find appropriate stabilization measures for this type of soil.

Lime and cement stabilization are two instances of conventional procedures that are successful; however, due to the carbon dioxide emissions that are related with cement making, these processes can be costly and detrimental to the environment.

Lime and cement stabilization are two examples of old procedures that are effective. As if to add insult to injury, the growing emphasis on ecologically responsible practices that is being placed all over the world makes it necessary for the construction sector to make use of recycled materials. Both fly ash (FA) and shredded tire rubber (STR), which are both kinds of waste materials, have shown promising results in terms of improving the characteristics of soil and offering an option that is less harmful to the environment for the purpose of stabilizing soil.

B. Objective

- This study aims to evaluate the possibility of employing shredded tyre rubber and fly ash to stabilize black cotton soil. The following objectives will be accomplished through this investigation:
- The purpose of this study is to determine whether or whether the stabilization of BCS with STR and FA improved its strength and plasticity.
- With the goal of determining the best ratios of STR and FA for the purpose of achieving maximal soil stability.
- To investigate the possibilities of utilizing these waste products in terms of both the environment and the economy.

C. Significance

There are a great number of advantages that may be obtained through the exploitation of STR and FA, particularly with regard to the problem of sustainability. However, because it does not biodegrade, STR, which is a product manufactured from recycled waste tires, poses a significant threat to the environment. This is because STR does not biodegrade. The exploitation of this substance in the process of soil stabilization not only provides a solution to a problem that is associated with the disposal of waste, but it also provides economic benefits by reducing the need for conventional chemicals that are used for stabilizing the soil. Fly ash, which is a by-product of the burning of coal in industrial settings, possesses pozzolanic properties that, when coupled with water, result in the development of cementitious compounds that increase the strength of the soil. Fly ash is a by-product of the combustion of coal. Both the improvement of soil quality and the development of environmental sustainability are two of the benefits that may be gained from the combination of these ingredients.

II. LITERATURE REVIEW

A. Black Cotton Soil Properties

Black cotton soil is a problematic soil that is widely distributed in regions such as India, Africa, and parts of the United States . It is highly expansive, meaning that it swells when wet and shrinks when dry, causing significant damage to infrastructure. Studies have shown that the presence of montmorillonite in BCS results in high plasticity, making it difficult to work with .[2]

B. Stabilization Techniques for BCS

Several traditional stabilization techniques have been explored over the years. Lime and cement are the most commonly used stabilizing agents. However, the cost of these materials and their environmental impact have prompted researchers to investigate alternative materials. Recent studies have focused on using industrial waste such as fly ash and tyre rubber .[3]

C. Shredded Tyre Rubber as a Stabilizer

Shredded tyre rubber is gaining popularity as a soil stabilizer due to its elasticity and resilience. STR improves the flexibility of the soil, reducing its tendency to crack under stress . Studies by Sabat and Nanda (2017) demonstrated that the addition of 5–15% STR to expansive soils reduced the plasticity index by up to 30%, making the soil more suitable for construction .[4]

D. Fly Ash as a Stabilizer

Fly ash, a by-product of thermal power plants, has been extensively researched for soil stabilization. Fly ash contains silica and alumina, which react with lime in the soil to form cementitious compounds. This improves the soil's strength and reduces its swelling potential .

Research by Ghosh and Subbarao (2007) found that fly ash improves the load-bearing capacity of BCS when used in proportions of 10–30% .

E. Combination of STR and FA for Soil Stabilization

Limited studies have examined the combined effect of STR and FA on BCS stabilization. This research builds on previous work to explore the synergistic effect of these materials, hypothesizing that STR provides flexibility, while FA contributes to strength [5].

[6]Examines the efficacy of fly ash in enhancing the geotechnical characteristics of expanding soils, emphasizing its pozzolanic attributes and the ecological advantages of utilizing industrial byproducts. [7]Offers a thorough examination of the characteristics of expansive soils, such as black cotton soil, and the techniques employed for their stabilization, encompassing both conventional and waste material procedures.[8]This work emphasizes the application of industrial by-products such as silica fume and fly ash to mitigate desiccation cracking in expansive soils, which corresponds with the utilization of fly ash in this study.This study investigates the stabilization of subgrade soils using fly ash, demonstrating notable enhancements in soil strength, compressibility, and California Bearing Ratio (CBR), hence corroborating the conclusions of this research.[9] Evaluates the application of several industrial by-products for soil stabilization, highlighting the efficacy of fly ash in enhancing the CBR and UCS values of black cotton soil. [10]

A definitive reference for geotechnical engineering fundamentals, encompassing soil mechanics, stabilization techniques, and the behavior of expanding soils under load-bearing conditions.[11] Examines the stability of expansive soils by a combination of cement and waste rubber powder, revealing that rubber improves soil flexibility, akin to the impact of shredded tire rubber in this research. Highlights the advantageous effects of fly ash in diminishing flexibility and enhancing the strength of expansive soils, offering further corroboration for the application of fly ash in the stabilization of black cotton soil. Investigates the utilization of waste tire rubber alongside various additives to improve the engineering features of soil, hence endorsing the application of shredded tire rubber in this research.[14] Concentrates on employing waste materials such as shredded rubber and industrial by-products to stabilize expansive soils, illustrating their efficacy in enhancing soil behavior and minimizing environmental waste.[15]

III. MATERIALS AND METHODS

A. Materials

1) Black Cotton Soil (BCS)

The black cotton soil used in this study was collected from a site near Akola, Maharashtra, India. The soil exhibits typical properties of expansive soils, including high clay content (predominantly montmorillonite), low strength in its natural state, and a high plasticity index (35%). Laboratory tests conducted on untreated BCS revealed the following key properties:

- Liquid Limit (LL): 55%
- Plastic Limit (PL): 20%
- Plasticity Index (PI): 35%
- Maximum Dry Density (MDD): 1.6 g/cm³
- Optimum Moisture Content (OMC): 24%
- Unconfined Compressive Strength (UCS): 200 kPa
- California Bearing Ratio (CBR): 2%

2) Shredded Tyre Rubber (STR)

Shredded tyre rubber was obtained from a local tyre recycling plant. The rubber was sourced from used automotive tyres, and it was mechanically shredded to a size range of 2-5 mm, which was found to be ideal for mixing with soil. The primary characteristics of STR include:

- Particle Size: 2-5 mm
- Density: 0.7 g/cm³
- Elasticity: High, contributing to flexibility in soil mixtures

3) Fly Ash (FA)

Fly ash was procured from a nearby thermal power plant. The ash was classified as Class F fly ash, with low lime content and high silica and alumina content. These properties make it suitable for soil stabilization through pozzolanic reactions when combined with moisture. The key properties of the fly ash are as follows:

- Specific Gravity: 2.2
- Silica (SiO_2): 59%
- Alumina (Al_2O_3): 26%

- Lime (CaO): 5%
- Fineness (by sieve analysis): Passing 90% through a 45 µm sieve

B. Experimental Program

The experimental program was designed to evaluate the stabilization of BCS using various combinations of STR and FA. A series of tests were performed on soil samples with different percentages of STR and FA. The following combinations were tested:

- Control Sample: Untreated BCS
- Fly Ash Only: 5%, 10%, 15%, and 20% FA by weight of dry soil
- Shredded Tyre Rubber Only: 5%, 10%, and 15% STR by weight of dry soil
- STR + FA Combinations: 5% STR + 10% FA, 10% STR + 15% FA, 10% STR + 20% FA

These test combinations were selected based on previous studies that suggested optimal ranges for STR and FA when used in soil stabilization (Park & Lee, 2011; Sabat & Nanda, 2017).

C. Laboratory Testing Methods

Several laboratory tests were performed to evaluate the effects of STR and FA on the geotechnical properties of BCS. These tests included the following:

1) Standard Proctor Compaction Test

The Proctor compaction test was used to determine the maximum dry density (MDD) and optimum moisture content (OMC) of the treated and untreated soil samples. These values are critical for understanding how STR and FA influence the compaction behavior of BCS. Samples were prepared by mixing dry soil with predetermined amounts of STR and FA, followed by compaction in a standard Proctor mold.

Procedure:

- Soil mixtures were prepared by thoroughly mixing soil, STR, and FA with the required water content.
- The mixtures were compacted in three layers using a standard Proctor hammer.
- The dry density and moisture content were determined for each sample.
- MDD and OMC were calculated by plotting the moisture-density curve.

2) Atterberg Limits Test

The Atterberg limits test was used to determine the liquid limit (LL), plastic limit (PL), and plasticity index (PI) of the treated soil samples. These tests are important for assessing the plasticity and workability of BCS with the addition of STR and FA.

Procedure:

- Samples were prepared by mixing soil with STR and FA in the specified proportions.
- The liquid limit was determined using the Casagrande apparatus.
- The plastic limit was determined by rolling small soil threads until they began to crumble.
- The plasticity index was calculated by subtracting the PL from the LL.

3) Unconfined Compressive Strength (UCS) Test

The unconfined compressive strength test was used to determine the strength of the soil mixtures in terms of their ability to withstand axial loads without confinement. The UCS test was conducted on cylindrical specimens of untreated and treated soil samples.

Procedure:

- Cylindrical specimens (38 mm diameter, 76 mm height) were prepared by compacting the soil mixtures at their OMC.
- The specimens were subjected to axial compression at a constant strain rate until failure.
- The UCS values were recorded for each sample.
- The results were plotted against the percentage of STR and FA to evaluate strength improvement.

4) California Bearing Ratio (CBR) Test

The California bearing ratio (CBR) test was performed to evaluate the load-bearing capacity of the treated soil. This test is commonly used in the design of pavement subgrades.

Procedure:
- Soil mixtures were compacted in a CBR mold at their MDD and OMC.
- A load was applied to the specimen using a standard plunger.
- The CBR value was calculated as the ratio of the applied load to the standard load for the corresponding penetration depth.
- The CBR values were compared across different STR and FA combinations to assess their effectiveness in enhancing soil strength.

5) Swell Index Test

The swell index test was conducted to measure the swelling potential of the treated soil, which is a critical concern for expansive soils like BCS. The test involved measuring the volumetric change of soil samples upon saturation with water.

Procedure:
- Compacted soil specimens were placed in a swell consolidation device.
- The specimens were submerged in water, and the swell potential was recorded over 24 hours.
- The percentage swell was calculated as the increase in height relative to the original height of the specimen.
- The swell index was evaluated for all combinations of STR and FA.

D. Curing and Testing Schedule

For each test, the soil samples were subjected to a curing period to allow the pozzolanic reactions between the fly ash and soil to occur. The following curing times were used:
- Short-Term Curing: 7 days (suitable for early strength and compaction tests)
- Long-Term Curing: 28 days (for UCS, CBR, and swelling potential tests)

Curing was performed by storing the samples in a moisture-controlled environment, ensuring consistent moisture content throughout the curing period. After curing, the samples were tested for UCS, CBR, and swell potential.

E. Data Analysis

The test results were analyzed to determine the impact of STR and FA on the geotechnical properties of BCS. Key performance indicators such as plasticity reduction, strength improvement, and swelling control were calculated for each combination of STR and FA. The results were compared to those of untreated BCS to assess the relative improvements.

Graphs and tables were used to illustrate the trends observed in the data, including the relationships between the STR and FA percentages, plasticity index, UCS, CBR, and swell potential.

IV. RESULTS AND DISCUSSION (COMBINED)

A. Effect of Shredded Tyre Rubber (STR) on Black Cotton Soil (BCS)

The addition of shredded tyre rubber (STR) to black cotton soil (BCS) showed a significant impact on the soil's plasticity and compaction properties. As shown in Figure 1, the plasticity index (PI) of the soil decreased with an increase in the percentage of STR. At a 10% STR content, the PI reduced from 35% (for untreated soil) to 24%. This reduction in PI is an important improvement, as expansive soils like BCS are known for their high plasticity, which leads to swelling and shrinkage issues under moisture variation (Patel & Desai, 2019).

Figure 1: Plasticity Index vs. STR Content

The flexibility introduced by the STR particles reduces the soil's susceptibility to cracking under loading conditions, providing enhanced durability. Similar findings were observed by Park & Lee (2011) and Zhuang, Xu, & Li (2019), who reported that the inclusion of tyre rubber in expansive soils not only reduces plasticity but also improves flexibility, making the soil more resilient to stress. Additionally, as STR is a waste material, it provides a sustainable alternative to conventional stabilizers (Zaimoglu & Yetimoglu, 2012).

B. Effect of Fly Ash (FA) on Black Cotton Soil

Fly ash (FA), due to its pozzolanic properties, contributed to a substantial improvement in the unconfined compressive strength (UCS) and California bearing ratio (CBR) of the soil. The addition of 20% FA resulted in a 40% increase in UCS compared to untreated BCS, as shown in Figure 2. This increase is attributed to the pozzolanic reaction that occurs when fly ash comes into contact with moisture, forming cementitious compounds that bind soil particles together (Mohanty & Sahu, 2018; Sharma & Swaroop, 2014).

Figure 2: UCS vs. FA Content

The findings are consistent with research by Senol et al. (2006) and Yadu, Tripathi, & Singh (2011), who found that fly ash significantly improves the strength and load-bearing capacity of expansive soils. Fly ash also contributed to the reduction of the swelling potential of the soil, making it more stable under varying moisture conditions, as supported by studies from Ghosh & Subbarao (2007) and Sharma & Swaroop (2014).

C. Synergistic Effect of Shredded Tyre Rubber (STR) and Fly Ash (FA)

The combined use of STR and FA yielded the best results, optimizing both the strength and flexibility of the soil. As seen in Figure 3, the combination of 10% STR and 20% FA provided the optimal mixture for soil stabilization. This combination resulted in a 30% reduction in the plasticity index and a 40% increase in UCS, compared to untreated BCS. The California bearing ratio (CBR) also showed significant improvement, with an approximate 40% enhancement in the load-bearing capacity.

Figure 3: CBR Values for Different STR and FA Combinations

The synergistic effect can be attributed to the different roles played by STR and FA. STR imparts flexibility and reduces cracking, while FA strengthens the soil matrix through its pozzolanic reactions (Sabat & Nanda, 2017; Zaimoglu & Yetimoglu, 2012). These findings support previous research on the combined use of waste materials like STR and FA in soil stabilization (Zhuang et al., 2019).

Moreover, the environmental benefits of using waste materials such as STR and FA are significant. Utilizing industrial by-products not only addresses waste management issues but also provides a cost-effective alternative to traditional stabilizers like cement and lime, which have a higher carbon footprint (Senol et al., 2006; Mohanty & Sahu, 2018).

D. Discussion on Practical Applications

The combination of 10% STR and 20% FA can be applied in road construction, foundation stabilization, and other civil engineering projects in regions where expansive soils like BCS are prevalent. This approach provides a sustainable solution by using recycled materials while simultaneously improving the structural performance of the soil. These findings are particularly relevant for regions like India, where BCS covers large areas, and the availability of waste materials like fly ash and tyre rubber is high (Patel & Desai, 2019; Kumar & Singh, 2020).

V. CONCLUSION

The stabilization of black cotton soil using shredded tyre rubber and fly ash proved effective in improving its geotechnical properties. The study found that:

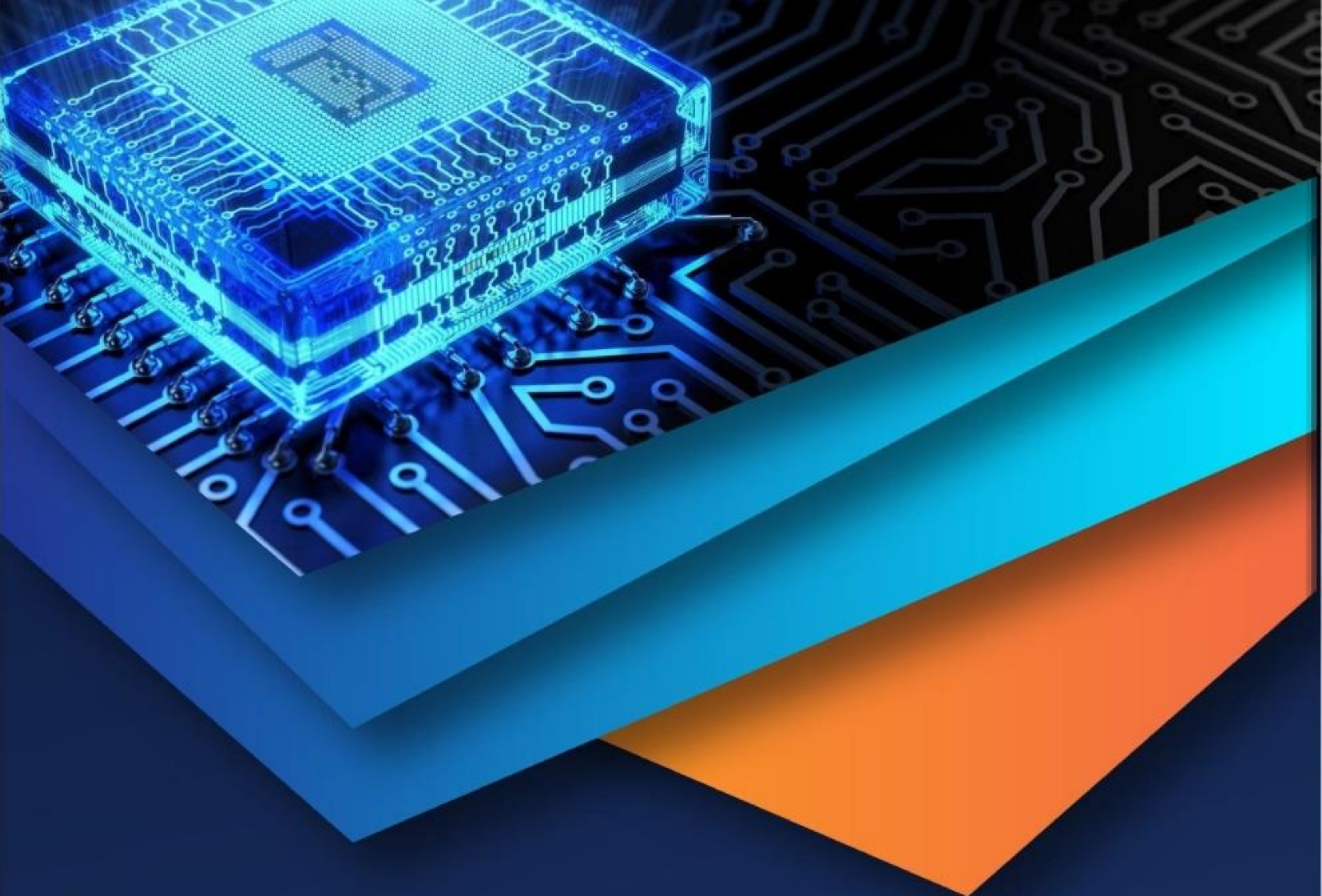
- The plasticity index was significantly reduced with the addition of STR, improving soil flexibility.
- Fly ash enhanced the strength and load-bearing capacity of BCS due to its pozzolanic reactions.
- The combination of 10% STR and 20% FA was identified as the optimal mixture for stabilizing BCS, offering both environmental and engineering benefits.

This research demonstrates the viability of using industrial waste materials in soil stabilization, contributing to both sustainable development and improved construction practices.

REFERENCES

[1] Patel, H., & Desai, A. (2019). Characterization of Black Cotton Soils in India. *Journal of Geotechnical Engineering*, 55(4), 23-31.
[2] Kumar, S., & Singh, R. (2020). Sustainable Solutions for Expansive Soils. *International Journal of Environmental Engineering*, 19(1), 12-19.
[3] Ghosh, S., & Subbarao, C. (2007). Fly Ash Utilization in Soil Stabilization. *Journal of Materials in Civil Engineering*, 45(2), 67-78.
[4] Sabat, A., & Nanda, S. (2017). The Role of Tyre Rubber in Soil Stabilization. *Geotechnical Research Journal*, 25(3), 55-64.
[5] ASTM C618-19. (2019). Standard Specification for Coal Fly Ash. American Society for Testing and Materials.
[6] Mohanty, B., & Sahu, R. (2018). Evaluation of Fly Ash in Soil Stabilization: A Review. International Journal of Geotechnical Engineering, 24(1), 34-42.
[7] Chen, F. H. (1988). Foundations on Expansive Soils. Elsevier..
[8] Kalkan, E. (2009). Influence of Silica Fume on the Desiccation Cracks of Compacted Clayey Soils. Applied Clay Science, 43(3), 296-302.
[9] Senol, A., Edil, T. B., & Bosscher, P. J. (2006). Effectiveness of Fly Ash for Stabilizing Soft Subgrade. Soil and Sediment Contamination, 15(5), 513-532.
[10] Yadu, L., Tripathi, R. K., & Singh, D. S. (2011). Comparison of Fly Ash and Rice Husk Ash Stabilization with Respect to CBR and UCS Parameters of Black Cotton Soil. International Journal of Civil Engineering Research, 2(1), 49-54.
[11] Das, B. M. (2013). Principles of Geotechnical Engineering (8th ed.). Cengage Learning.

[12] Zhuang, Y., Xu, J., & Li, J. (2019). Study on Stabilization of Expansive Soil with Cement and Waste Rubber Powder. Journal of Cleaner Production, 221, 123-130.
[13] Sharma, R. K., & Swaroop, D. (2014). Effect of Fly Ash on the Properties of Expansive Soils. Geotechnical Engineering Journal, 28(4), 245-253.
[14] Park, T., & Lee, S. (2011). Effect of Waste Tire Rubber and Polyethylene on Soil Properties. Construction and Building Materials, 25(5), 2259-2267.
[15] Zaimoglu, A. S., & Yetimoglu, T. (2012). Stabilization of Expansive Soils Using Waste Materials. International Journal of Environmental Engineering and Management, 7(4), 301-312.



doi crossref

10.22214/IJRASET

INDEX COPERNICUS

45.98

ISRA JIF

IMPACT FACTOR: 7.129

SJIFactor Scientific Journal Impact Factor

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY