

SOIL IMPROVEMENT IN PROBLEMATIC BLACK COTTON SOIL BY USING DRY KOTA STONE SLURRY AND FLY ASH-A STATE OF ART OF REVIEW

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Abstract

Black Cotton Soil is particularly rapid-expanding and swelling when it meets water. This trait of soil results in extremely low soil strength and other attributes. Soil stabilization by various stabilizers is required to enhance its characteristics. Stabilization is a technique used to improve the soil's structural integrity. Soil stabilization raises the subgrade's load-bearing capacity, allowing it to better support the pavement and foundation. This is accomplished by increasing the soil's shear strength and regulating its shrink-swell qualities. Expansive soils could have their engineering qualities enhanced via several different means. The problematic soils are either excavated and replaced with excellent, higher-quality material, or treated with an additive. This paper demonstrates an analysis for soil improvement in problematic Black Cotton Soil by using dry Kota Stone Slurry and Fly Ash. Fly Ash is a byproduct of coal combustion in thermal power plants. It consists of fine particles that are carried away with the flue gases during the combustion process. The findings highlight its potential to address soil-related issues, enhance agricultural productivity, and contribute to sustainable land utilization practices.

Keywords: Black Cotton Soil; Fly Ash; Kota Stone Slurry; Soil Stabilization; Optimum Moisture Content

Introduction

Suitable cotton-growing soil, predominantly black in color, is prevalent in various regions including the western half of Madhya Pradesh, parts of Andhra Pradesh, Karnataka, southern Rajasthan, the Deccan plateau, and Uttar Pradesh, encompassing 20-25% of India's total land area. However, Black Cotton Soil poses challenges due to its tendency to expand

with moisture during the rainy season and contract during dry periods. While fertile for farming, Black Cotton Soil is unsuitable for construction due to its instability. Conversely, Kota stones, commonly found in the Kota region and Jhalawar District of Rajasthan, are prized for their versatility in wall cladding and floor embellishment. However, the

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stone industry generates substantial waste in the form of stone slurry, posing environmental and health hazards. This slurry, known as Kota Stone Slurry, finds applications as a filler, stabilizer, and pozzolanic material despite its negative impacts on soil fertility, aquifer pollution, and airborne dust particles.

Soil Stabilization

The term ‘soil stabilization’ discusses the procedure of enhancing a soil’s strength or bearing capacity using appropriate admixtures or stabilizers, such as using controlled compaction. Stabilization could boost soil shear strength and control shrink or swell conditions in order to better maintain pavements and foundations. Stabilization is used in many different contexts, including but not limited to roads, parking lots, site development projects, airports, and many more. Whether it’s expanding clays or granular materials, stabilization could be employed to remediate the subgrade. Fly Ash, Rice Husk, Lime, Portland Cement, etc. are some of the ingredients used in this method. The benefits of soil stabilization include Stabilization could be used for a variety of purposes, including but not limited to those listed below: cost reduction, increased soil strength, prevention of hidden settlement, enhanced soil workability, decreased dust levels in the workplace, and enhancement of the engineering features of soil to render it acceptable for building. Building a Dam or Reservoir, Laying Pipelines, and Paving Roads (Afrin, 2017). In the United States, sand/clay combinations were used in the first soil stabilization tests, which were completed in about 1906. Road construction soil stabilization techniques were first used in Europe in the 1930s and 40s of the 20th centuries (Kézdi, 1979). Soil quality could be enhanced by adding Portland cement, Fly Ash, bitumen, or a mixture of these materials before being fully mixed and compacted into the pavement (Mehta *et al.*, 2013). The soil’s categorization and the intended level of improvement determine the kind of addition and the quantity needed.

The article by Nhieu *et al.* (2023) investigates the use of a novel stabilizing agent, a combination of cement and natural rubber latex, to improve the properties of recycled concrete aggregate (RCA) for pavement base material. The study aims to enhance the strength, durability, and performance of RCA for sustainable pavement construction.

The article by Hoy *et al.* (2023a) evaluates the stiffness, rutting, and fatigue performance of cement-natural rubber latex stabilized recycled concrete aggregate (RCA). Their study assesses the effectiveness of this stabilization technique in

improving the mechanical properties of RCA for pavement applications.

The study by Hoy *et al.* (2023b) highlights the impact of wetting and drying cycles on the mechanical strength of cement-natural rubber latex stabilized recycled concrete aggregate (RCA). They discuss how these environmental conditions affect the performance and durability of the stabilized RCA, providing insights for optimizing its use in construction applications.

The study by Udomchai *et al.* (2022) assesses the durability of cement-natural rubber latex stabilized unpaved roads under cyclic tensile loading and wetting and drying cycles. Their research focuses on understanding how these environmental factors influence the performance and longevity of stabilized unpaved roads, providing valuable insights for sustainable infrastructure development

Kumar and Choudhary, (2022) Kumar and Choudhary’s study investigated the durability of cement-natural rubber latex stabilized unpaved roads subjected to wetting and drying cycles and cyclic tensile loading. Their findings suggest promising durability characteristics for this stabilization method, highlighting its potential for improving the performance of unpaved roads. However, further research is needed to assess long-term performance and practical implementation. This study contributes valuable insights to the field of sustainable road stabilization techniques, informing future infrastructure development efforts.

Puppala *et al.* (2020) study demonstrates the effectiveness of using crushed slag and fly ash as replacements for cement in stabilizing marginal lateritic soil for pavement applications. Their findings suggest that these materials improve the engineering properties of the soil mixture, offering potential for cost-effective and environmentally sustainable pavement construction. Further research is needed to validate these results in field conditions and optimize mixture proportions. Overall, this study provides valuable insights into alternative methods for pavement stabilization, with implications for enhancing infrastructure sustainability and performance.

Puppala *et al.* (2021a) showcases the enhanced mechanical properties and microstructure of cement-stabilized lateritic soil for pavement applications through the incorporation of recycled materials and natural rubber latex. Their findings suggest a potential for sustainable pavement construction practices. Further research may be needed to validate these results in field conditions and optimize the mixture composition. Overall, this study offers valuable insights into improving

pavement performance while promoting environmental sustainability.

Puppala *et al.* (2022) study illustrates the enhanced fatigue properties of cement-stabilized recycled materials and lateritic soil for sustainable pavement applications with the addition of natural rubber latex. These findings underscore the potential for sustainable and resilient pavement construction practices. Further research could focus on field validation and optimization of the proposed mixture for real-world applications. Overall, this study provides valuable insights into improving pavement performance while promoting environmental sustainability.

Puppala *et al.* (2021b) study investigates the wetting-drying durability performance of cement-stabilized recycled materials and lateritic soil with natural rubber latex. Their findings suggest promising durability, highlighting the potential for sustainable pavement applications. Further research could focus on field validation and optimizing the mixture for practical use. Overall, this study provides valuable insights into enhancing pavement durability while promoting environmental sustainability.

Black Cotton Soil and its type

When wet, Black Cotton Soil is very unstable due to its expansive nature and high fluctuations in volume (Eko and Riskowski, 2001). These soils have a high clay concentration, making them swell in wet conditions and contract in dry ones. It is necessary to enhance the qualities of this soil to compensate for this deficiency. This soil is prevalent in the north-eastern region of Nigeria, but its widespread coverage makes it impractical to either avoid it or locate a suitable alternative. Black Cotton Soil has traditionally been stabilized with lime and cement to improve its geotechnical qualities. It was shown in (Basha *et al.*, 2005) that lime and lime admixed with cement significantly enhanced the geotechnical qualities of Black Cotton Soils. The deployment cost as a stabilizer is high, even though the material's qualities have been much enhanced. Research engineers' attention has been piqued by the financial implications of addressing soil deficiencies by using locally accessible materials that have the potential to be both cost-effective and readily available (Aliyu, 2020). Figure 1 depicts the architecture of Black Cotton Soil

The idea of stability has been around for at least the last five thousand years. Ancient cultures in Mesopotamia and Egypt employed treated earth roads, while cultures in Greece and Rome used soil-lime combination (Chakraborty *et al.*, 2016). Black soil is categorized based on the thickness of layers into three subgroups:



Figure 1. Structure of Black Cotton Soil

1. Shallow Black Soil

Black soil that is less than 30 centimetres in depth is considered shallow. The Satpura hills of Madhya Pradesh, the cities of Bhandara, Nagpur, and Satara in Maharashtra, and the regions of Bijapur and Gulbarga in Karnataka are all home to this species. These soil conditions are ideal for growing, rice, jowar, gram, cotton, and wheat.

2. Medium Black Soil

The average depth of 30-100 centimetres in medium black soil. It extends across a wider area that includes Andhra Pradesh, Tamil Nadu, Maharashtra, Madhya Pradesh, and Gujarat.

3. Deep Black Soil

The thickness exceeds 1 meter. It occupies a sizable portion of the lowlands of the Indian peninsula. Between forty and sixty percent of the mass is composed of clay, and it has an alkaline response. The soil is rich and ideal for growing a wide variety of crops, including cotton, sugarcane, rice, citrus fruits, vegetables, and so on (indiaagronet(n.d.)).

Problem with Black Cotton Soil

India is home to several of the California Bearing Ratio (CBR) method's creators. With both in-lab and on-site CBR measurements with Black Cotton Soils, this approach requires a 15-kg surcharge weight to account for the soil type's tendency to swell. The swelling pressure and edema caused by Black Cotton Soils range from 20 to 80 tons per square meter. Therefore, CBR values are neither credible nor supported by science since they are calculated by arbitrary methods (Katti, 1978). It is quite unlikely that paved roads could have a total thickness of 830 millimetres under conditions of CBR 2% and commercial vehicle traffic of 4500 per day. So that it could fit into the greater soil area (Suneetha and Prasad, 2017). The crust thickness of the stiff pavement is between 300 and 320

millimetres, which allows for some pliability. The thickness just must be a third as much for flexible pavement (Scheingross, 2016). Black Cotton Soil seems to be a good fit for cement concrete pavement. This kind of pavement has the potential to lessen the need for emergency repairs on the project. The alternative is to make use of semi-rigid substructures. First, the correct method must be explained, and only then can the crust's thickness be calculated. It would reduce the quantity of crust required. Extreme traffic causes damage to both the compacted berm and the uncompacted berm (which received no treatment). Trapped front ends have been known to cause catastrophic incidents involving huge vehicles. Therefore, BMS must be established as an alternative benchmark (Thoke and Naktode, 2021). Common issues with Black Cotton Soil include:

- **High Compressibility:** When wet, Black Cotton Soil is very flexible and compressible. The footing, while resting on such soils, experiences significant consolidation settlements.
- **Swelling:** When the natural water content of the soil is low, as it is during the dry season, the structure moves at different rates during the wet season. This leads to the lifting and cracking of buildings resting on such swollen soils. Swelling pressures must have reached a certain level before the structure could be used.
- **Shrinkage:** If a building was built around the end of the rainy season, when natural water content is high, it would have settlement and shrinkage cracks (Singh and Vasaikar, 2013).

Characteristic of Black Cotton Soil

Soils with high compressibility than a colour range from dark reddish brown to black, known as 'Black Cotton Soil', could be found at depths of 0.5 to 10 meters. The following Table 1 records the often-observed features of Black Cotton Soil (Pallavi and Poorey, 2016):

Properties of Black Cotton Soil

Black Cotton Soil covers 25% of India's land area, making it one of the most frequent soil types. The Black Cotton Soil has a clayey texture and varies in colour from gray to black. Black Cotton Soil is formed primarily from the weathering of volcanic and basaltic rock. The presence of titanium oxide gives Black Cotton Soil its distinctive color. It has been observed that black cotton soil includes montmorillonite, a clay mineral with high expansion capabilities. In this experiment, Black Cotton Soil was carried from the Porbandar district of Saurashtra. There are pockets of black cotton soil along Gujarat's western coast. Table 2 shows some

of the index properties of Black Cotton Soil (Eqyaabal and Ambica, 2015).

Table 1. Characteristics Raw soil sample of Black Cotton Soil

S.No	Geotechnical Properties	Values
1.	Specific Gravity	2.65
2.	Particle Size:	
	Gravel Content	0%
	Coarse Sand	0%
	Medium Sand	1%
	Fine Sand	0%
	Silt and Clay	99%
3.	Atterberg's Limits:	
	Liquid Limit	65%
	Plastic Limit	40%
	Plasticity Limit	25%
4.	Optimum Moisture Content	24%
5.	Maximum Dry Density	13.24KN/m ³
6.	Free Swell Index	65%
7.	Soil Classification	CH

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Chemical Interactions and Mechanisms

1. Pozzolanic Reactions:

- **Fly Ash:** Fly Ash contains silica (SiO_2), alumina (Al_2O_3), and lime (CaO), which react with calcium hydroxide ($\text{Ca}(\text{OH})_2$) present in the soil or added through lime, forming calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-H). These hydration products contribute to the increased strength and durability of the stabilized soil.
- **Kota Stone Powder (KSP):** Primarily composed of calcium carbonate (CaCO_3), KSP undergoes carbonation, leading to the formation of calcite, which helps in binding soil particles together, enhancing the soil's load-bearing capacity.

2. Cation Exchange and Flocculation:

- **Black Cotton Soil:** The high cation exchange capacity of BCS facilitates the replacement of exchangeable cations (e.g., Na^+) with calcium ions

(Ca²⁺) from FA and KSP. This ion exchange reduces the plasticity index of the soil and promotes flocculation, where soil particles aggregate, improving the soil's structural integrity.

Physical Interactions and Mechanisms

1. Particle Size Distribution and Packing:

The fine particles of FA and KSP fill the voids between larger BCS particles, reducing the soil's porosity and increasing its dry density. This filler effect enhances the compaction and mechanical strength of the stabilized soil.

2. Microstructural Changes:

SEM Analysis: Scanning Electron Microscope (SEM) images of treated soil samples reveal a denser and more cohesive soil matrix. The presence of C-S-H and C-A-H compounds, along with calcite crystals, indicates successful pozzolanic and carbonation reactions, leading to improved soil stability.

Laboratory Test Results

To quantify the improvements in soil stability, several laboratory tests were conducted on samples of Black Cotton Soil stabilized with varying proportions of Fly Ash and Dry Kota Stone Slurry.

1. Unconfined Compressive Strength Tests:

UCS tests were performed to evaluate the strength of the stabilized soil. The results indicated a significant increase in UCS values with the addition of FA and KSP.

2. California Bearing Ratio (CBR) Tests:

CBR tests assessed the bearing capacity of the stabilized soil. Enhanced CBR values indicated improved load-bearing capacity, essential for construction applications.

3. Durability Tests:

Wet-Dry and Freeze-Thaw Cycles: Samples treated with FA and KSP were subjected to wet-dry and freeze-thaw cycles to evaluate their durability under environmental stress. The results showed minimal mass loss and maintained high residual strength, indicating superior durability.

The laboratory results provide strong empirical evidence supporting the use of Fly Ash and Dry Kota Stone Slurry in stabilizing of Black Cotton Soil. The significant increases in UCS and CBR values demonstrate that the pozzolanic and carbonation reactions improve the soil's strength and

load-bearing capacity. The filler effect and microstructural changes observed through SEM analysis further corroborate the enhanced physical properties of the stabilized soil.

Key Findings:

- **Strength Improvement:** The UCS tests showed up to a 275% increase in strength after 28 days, with higher proportions of FA and KSP resulting in greater improvements.
- **Bearing Capacity:** CBR values increased by up to 267%, indicating a substantial enhancement in the soil's load-bearing capacity.
- **Durability:** Treated samples exhibited excellent durability under wet-dry and freeze-thaw cycles, with minimal degradation.

Review Methodology

This systematic review's methodology is based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria. PRISMA is a concise set of guidelines for performing systematic reviews and meta-analyses. It is frequently used for reporting reasons that investigate the outcomes of involvement. It can also follow systematic reviews that ignore interferences in favor of focusing on factors such as prevalence, diagnosis, or outcome.

Search Strategy

This Systematic Literature Review looks at soil growth in problematic Black Cotton Soil using dry Kota Stone Slurry and Fly Ash principles, as well as the associated benefits in terms of dependability, trustworthiness, organization, and transparency.

The data came from four main academic literature databases: Science Direct, IEEE, Springer, and Scopus. Researchers consult Previously Conducted Research Studies to learn about previous studies on a certain research topic or area. To identify relevant academic information, databases were searched many times using the same keywords; the most recent search was on January 25th, 2022. Scopus and other databases were thoroughly searched for keywords that appeared in both the topic and title, as well as the subject, title, and abstract. Only articles, reviews, conference papers, and reviews were accepted, together with proceedings and bibliographic sources.

Table 3 shows the words searched for in Scopus and Near. Several different spellings of the keywords were also investigated. This collection had a total of eight files. Table 3 shows a collection of keywords and their intended usage.

Table 3. Search strategy keywords

S. No.	Keywords
1	What are the Black Cotton Soil and its types?
2	What is the influence of dry Kota Stone Slurry and Fly Ash on the shear strength parameters of Black Cotton Soil?
3	What are the effects of Dry Kota Stone Slurry and Fly Ash on the geotechnical properties of Black Cotton Soil?
4	What are the key characteristics and properties of problematic Black Cotton Soil?
5	Can the use of Dry Kota Stone Slurry and Fly Ash mitigate the swell-shrink behaviour of problematic Black Cotton Soil?
6	What is the long-term stability of problematic Black Cotton Soil treated with Dry Kota Stone Slurry and Fly Ash?

1. The Journal Selected for Research

In 2022, the author reviews Elsevier's Journal of "Engineering Geology" to see how frequently the most relevant papers were mentioned in previous research. A keyword was used to find relevant articles with no limits. To select the most suitable publication for the research, the findings were separated into two categories: those aimed to verify and establish the research's dependability, and those intended to collect information.

Researchers used a keyword search based on product names to find companies that manufactured one of the top five best-selling products in 2019 or ten or more distinct devices in the first wave of new releases slated for 2020. The articles were then sorted based on keywords in their titles, abstracts, and methods sections. This was done to (1) eliminate irrelevant articles from the study and (2) identify which additional items were included in the trials. Then they prepared a list of items in this category and issued a new round of questions, one for each. In the end, eleven additional people were added. In the results section, the team presents their findings, including a list of the keywords used to locate each item.

Scrutinizing of paper for study

The Primary Studies (PS) selection technique consists of four stages: identification, admission,

inclusion, and screening. The first step is to identify each relevant research; the initial search generated 2375 results.

The papers presented at these conferences were found by a thorough search of many digital libraries and archives, including Science Direct, Springer, Scopus, and IEEE Xplore, all of which provided full-text access. After deleting duplicates and organizing the data, they were left with 217 studies, 28% of which were focused with diagnosing emotional stress, 17% with verifying scientific viability and consistency, and 33% with exploratory investigations into cutting-edge scientific applications and innovations. In the second phase, conduct a preliminary assessment by reading the article's title, keywords, and abstract. So far, 2335 items have been excluded owing to a failure to meet inclusion requirements, the majority of which are linked to the study scope and the optimization subject. These two records, along with the questionable and comprised records, were referred for additional review. Figure 2 depicts the findings of an inspection of a systematic review database.

The bibliography must include all relevant publications and reviews, which requires extensive research. All other paperwork was evaluated as well. To select which studies should be included and which should be eliminated from the current systematic review, the authors used the criteria stated in Table 4 to evaluate their additional material and abstracts. permeability, and enhanced compaction characteristics

Table 4. Systematic Review Criteria for Inclusion and Exclusion

Inclusion Criteria	Exclusion Criteria
I1: The paper should be peer-reviewed	E1: Papers that do not focus on the body stress-related study.
I2: The paper should be in the English language.	E2: Grey literature
I3: No time frame limit for publication	E3: Duplicate research and publications
I4: Papers should be published in research or full-article publication.	E4: Ph.D. theses, working papers, and project deliverables
I5: Standard of paper was blind to impact factor	

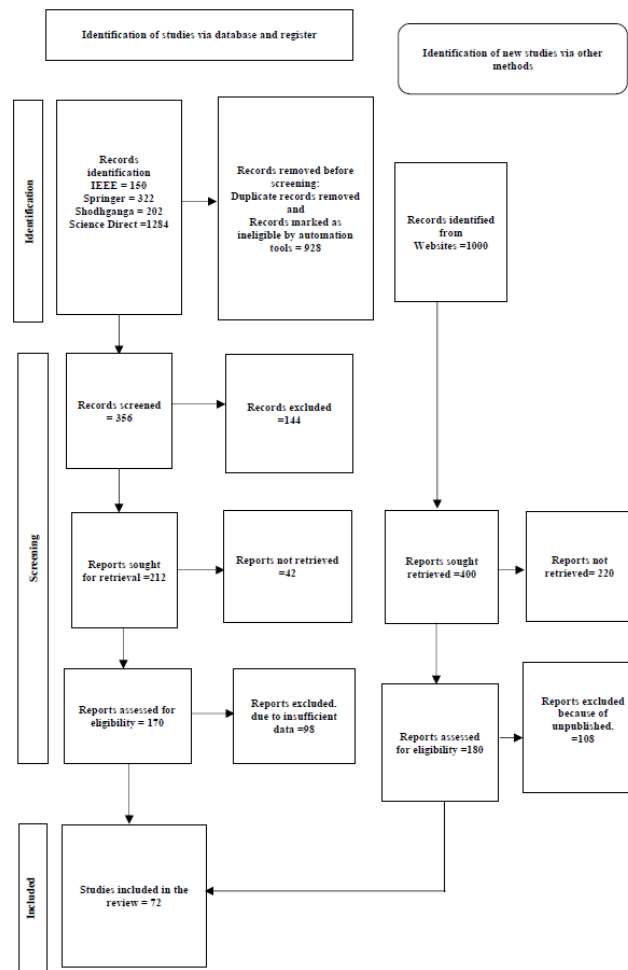


Figure 2. Schematic representing the steps involved in doing a database-wide systematic literature search

- Assessing the long-term performance and durability: The research aims to analyze the long-term behavior and durability of the improved soil using Dry Kota Stone Slurry and Fly Ash. This may involve studying the soil's resistance to weathering, erosion, and other environmental factors over an extended period.
- Developing guidelines and recommendations: Based on the research findings, the objective is to provide practical guidelines and recommendations for using Dry Kota Stone Slurry and Fly Ash as soil improvement techniques for problematic Black Cotton Soil. These guidelines could include optimum mix proportions, construction techniques, and maintenance practices for achieving sustainable and cost-effective soil stabilization.

Overall, these research objectives seek to understand the effects of Dry Kota Stone Slurry and Fly Ash on the problematic Black Cotton Soil and provide insights into their potential as soil improvement materials.

These SRs attempt to develop an open-source knowledge platform to support future researchers by gathering and assessing essential findings from prior research, identifying and comparing these findings, and noting obstacles and limitations that have happened as a result of the study. The existing level of knowledge in the field was used to conduct research and analysis for soil improvement in problematic black cotton soil utilizing dry Kota Stone Slurry and Fly Ash. This section analyzes and evaluates various sorts of investigators and their methodologies, with an emphasis on the three key research questions posed during the study's design phase. The following are the investigative questions.

RQ 1: How does the addition of dry Kota Stone Slurry and Fly Ash affect the compaction characteristics of Black Cotton Soil?

RQ 2: What is the effect of Fly Ash on the engineering behaviors of problematic Black Cotton Soil?

RQ 3: What are the advantages of Black Cotton Soil?

To begin achieving these goals, a thorough literature study was conducted. Citation indexing databases and the Internet of publications were searched using Sage, Emerald, Google Scholar, MDPI, Science Direct, IEEE Xplore, and Springer Link to locate papers published during the previous ten years that were relevant to the study issue. In addition, a web search was undertaken to identify the leading producers of wrist-mounted technology. White papers, production manuals, and scientific literature were used to compile the data.

Literature of Review

This section draws on research from a variety of sources, both published and theoretical and the comprehensive literature review is summarized here.

Priya *et al.* (2020) suggested that to make better use of expansive soil in construction by incorporating waste elements like Fly Ash and rice husk ash into Black Cotton Soil to make it more stable and resistant to shrinkage and swelling. Laboratory procedures such as the liquid limit, plastic limit, standard proctor test (mild compaction), CBR test, and others could be used to examine the material. The authors observe the influence of Fly Ash and rice husk ash on improving the performance of Black Cotton Soil, therefore a soil sample was mixed with Fly Ash at percentages of 5%, 10%, 15%, and 20%, and rice husk ash at percentages of 10%, 15%, 20%, and 25%.

Yin *et al.* (2022) examine the technological features of Black Cotton Soil stabilized with various amounts of natural lime, Volcanic Ash (VA), and a combination of the two. The findings demonstrated that the engineering features of Black Cotton Soil were significantly enhanced by the addition of VA and lime. Better results were seen when VA and lime were used to stabilize Black Cotton Soil. Natural CBR values multiplied by 10.76, plasticity decreased by 29%, and swell percent was reduced by 88% when 3% lime and 20% VA were added. The minimal swell, plasticity, and strength criteria are all met by stabilized Black Cotton Soil made with 3% lime + 20% VA, therefore it could be used in place of cutting and filling.

Akpan Paul *et al.* (2022) examine the effects of mechanical and chemical stabilization on Black Cotton Soil from the Eket senatorial district, which could expand and shrink. In this analysis, a combined mechanical and chemical approach to stabilization was used. The findings demonstrate that for all Black Cotton Soil from In Etet, Ikot Abasi, and Eastern Obolo, the Optimum Moisture

Content (OMC) of stabilized Black Cotton Soil increases as the percentage of Bagasse Ash (BA) replacement increases from 0% to 12%. The MDD increased concurrently with increasing the partial replacement of lime from 0% to 12% in stabilized black cotton soil from three sites in the Eket senatorial district, while it dropped with increasing the partial replacement of BA from 0% to 12%.

Sharma *et al.* (2020) demonstrate how Kota stone dust was successfully used to enhance the subgrade properties of Black Cotton Soil. MDD and OMC equal to 3% to 24% of Kota Stone Slurry dust mixed with Black Cotton Soil in the variation of 3% were obtained using standard compaction tests performed in a laboratory. After determining OMC and MDD in varied proportions, laboratory CBR experiments were performed using the aforesaid proportion of Kota Stone Slurry dust, and the findings showed that the soaked CBR value of Black Cotton Soil blended with 18% Kota stone dust increased from 2.12 to 8.37, or 295%.

Chouhan *et al.* (2021) examined the effects of varying the percentage of Kota Stone Slurry to cement in mortar mixes (1:5) from zero to twenty percent in 2.5% increments. The energy needed to extract these resources, as well as process and dispose of their waste, was substantial. The fine fragments created during the polishing of stones pose a significant threat to human and environmental health. The density, compressive, flexural water absorption, tensile, and adhesive strengths of a total of nine mortar mixtures were analyzed. The study found that the Kota Stone Slurry could be used as a partial cement substitute (up to 10%).

Jangid *et al.* (2018a) focused on the behavior of Black Cotton Soil at varying concentrations. Kota Stone Slurry concentrations ranging from 5% to 30% are incorporated into Black Cotton Soil for this study. Tests are also used to establish engineering specifications. Atterberg's limits (Liquid Limit, Plastic Limit, and Plasticity Index), a standard proctor test, a Differential Free Swelling (DFS) index, a swelling pressure test, and a wet sieve analysis are used to examine the behavior of Black Cotton Soil amended with varying concentrations of Kota Stone Slurry.

Tak *et al.* (2021) suggested using the Kota Stone Slurry Powder as a stabilizing agent for Black Cotton Soil. The investigations led to the conclusion that incorporating a certain percentage of Kota Stone Slurry Powder into Black Cotton Soil improves its engineering qualities such as its shrinkage limit, MDD, OMC, and Unconfined Compressive Strength (UCS). When the amount of Kota Stone Slurry Powder in expansive soil is increased, its swelling properties, including

a reduction in the swelling percentage and swelling pressure, are enhanced as well. More than 20% slurry mixing reduces UCS value.

Khatti *et al.* (2018) address the issue of creating a flexible pavement utilizing Black Cotton Soil, Recron 3s fiber, and Kota Stone Slurry in varying percentages (at least 15%). In this study, the Recron 3s fiber concentration ranges from 0.5 to 2.5 percent when combined with a Kota Stone Slurry of 15 percent in Black Cotton Soil. The results of testing are also used to establish the engineering parameters. Atterberg's limitations (Liquid Limit, Plastic Limit, and Plasticity Index), Sieve analysis, the standard proctor test, and the CBR are used to analyze the behavior of Black Cotton Soil mixed with various percentages of Kota Stone Slurry for pavement.

Rathore and Parbhakar (2018) calculated that using stone slurry waste makes the Black Cotton Soil more stable. This study was to determine the effect of stone slurry waste on the strength, compaction, and CBR qualities of Black Cotton Soil by combining the two in varying proportions. Direct shear, compaction, and CBR were identified to be the fundamental features. The findings reveal that the Black Cotton Soil is significantly improved by the addition of stone slurry waste, demonstrating the efficiency of this commercial waste in this context.

Kulkarni *et al.* (2016) present an approach to stabilizing Black Cotton Soil utilizing a combination of BA and lime. Bagasse is the fibrous by-product of burning sugarcane stalks that are left over after sugar is extracted. BA was shown to have pozzolanic qualities due to its high silica content and other pozzolanic elements including potassium, iron, calcium, aluminum, and magnesium. This study compared the effects of lime, ash, and a mixture of the two on the characteristics of expanding clay soil. The objective is to affordably enhance the engineering qualities of the Black Cotton Soil so that structures erected on it can effectively resist applied loads.

Gohel *et al.* (2016) purpose of this effort is to use Fly Ash and Lime to stabilize the soil. Testing has been performed with 5%, 10%, and 15% Fly Ash content, in addition to 4%, 8%, and 12% lime content. The empirical study depends on varying percentages of Fly Ash and lime content in the soil, and it was conducted on tests for soil Liquid limit, Plastic limit, C.B.R. test, Unconfined Compression Test, and Standard Proctor Test. The engineering qualities of the Black Cotton Soil would, with any fortune, see some improvements because of these endeavours.

Rajput and Yadav (2015) explain a test evaluating the effectiveness of increasing concentrations of Fly Ash in improving the qualities of expansive soil. Liquid limits, plasticity indices, and swelling indices have been shown to vary considerably. DFS fell from 52% to 14%, liquid limit decreased from 55.2% to 36.3%, and plasticity index decreased from 27.1% to 18.1% in expansive soil. Findings from the compaction test revealed an increase in OMC from 19% to 23% and a drop in MDD from 1.63g/cc to 1.52g/cc. The results of the tests suggest that the qualities of Black Cotton Soil might be enhanced by the addition of Fly Ash.

Table 5 presents the authors' study approach as well as an overview of the relevant literature.

Polypropylene Fibre (PPF)

A synthetic fiber made by polymerizing propylene; PPF is a linear polymer. It is advantageous in several ways, including its low weight, high strength, high toughness, and corrosion resistance. There are several applications for PPF, including the petrochemical sector, the energy sector, the apparel sector, environmental protection, and the building sector (Pérez-Rocha *et al.*, 2015; Tapiero *et al.*, 2019; Ali *et al.*, 2020). Constructing with concrete is problematic because of the material's low tensile strength, weakness in deformation resistance, and poor fracture resistance. The permeability of the concrete is enhanced by the ease with which microcracks can be generated from the outside to the inside. The concrete's inside is highly permeable to water or other hazardous ions, which speeds up its breakdown. (Hussain *et al.*, 2020) The addition of PPF to concrete causes a three-dimensional random distribution network structure to emerge, which effectively prevents the formation and growth of microcracks (Shen *et al.*, 2020). Therefore, the PPF could block the penetration of water and potentially damaging ions into the concrete. Adding PPF to concrete increases its durability. (Çelik and Bingöl, 2020; Li and Liu, 2020) PPF's high quality makes it suitable for application in structural engineering, pavement engineering, and even hydraulic engineering (Pang *et al.*, 2020). Figure 3 also includes graphic representations of PPF (Liu *et al.*, 2021).

Table 5. Summary of Literature Review

Authors	Techniques	Outcomes
Priya <i>et al.</i> (2020)	Fly Ash and Rice Husk Ash	Based on the findings, FLY ASH and rice husk ash could be utilized as soil stabilizers since they both raise CBR after being soaked and before being employed, by percentages of 5% and 10%, respectively.
Yin <i>et al.</i> (2022)	Stabilization	The results of this investigation showed that the pliability of BLACK COTTON SOIL was greatly diminished by both lime and VA.
Akpan Paul <i>et al.</i> (2022)	Mechanical and Chemical Stabilization	When BA and lime admixtures were employed to stabilize BLACK BLACK Black Cotton Soil mechanically and chemically from the three sites, identical features in OMC and MDD were created.
Sharma <i>et al.</i> (2020)	Stabilization	The ultimate optimal blend of waste materials combined with Black Cotton Soil is an enhanced construction material that provides significant cost savings in the building of flexible pavement design.
Chouhan <i>et al.</i> (2021)	Kota Stone Slurry	Based on the findings of this study, Kota Stone Slurry might be utilized as a partial substitute for cement at a rate of up to 10%.
Jangid <i>et al.</i> (2018)	Kota Stone Slurry	UCS values are found to be at their highest on 15% mix specimens and to diminish following further Kota Stone Slurry mixing.
Tak <i>et al.</i> (2021)	Kota Stone Slurry Powder	The gravity of a mixture of Kota Stone Slurry Powder and Black Cotton Soil is found to rise steadily with increasing percentages, while the impact is small.
Khatti J. <i>et al.</i> , (2018)	Black Cotton Soil With Kota Stone Slurry	CBR values are as high as 10.15 %and are achieved with a 2.05% fiber mix specimen combined with a 15% Kota Stone Slurry in Black Cotton Soil.
Rathore and Parbhakar (2018)	Kota Stone Slurry	Therefore, it is established that the shear strength parameter of Black Cotton Soil could be increased by using slurry composed of 15% Kota stone.
Kulkarni <i>et al.</i> (2016)	BA and Lime	Based on the study's findings, it has been shown that a ratio of 2:3 BA to Lime is optimal for stabilizing Black Cotton Soil.
Gohel <i>et al.</i> (2016)	FLY ASH And Lime	The highest value of UCS and CBR is achieved with an addition of 15% Fly Ash; as the percentage of Fly Ash in the mixture increases, this value begins to decrease.
Rajput and Yadav, (2015)	Fly Ash	The findings show that the level of expansiveness has decreased to a modest level. According to the findings, Fly Ash can alter the properties of expansive clay like Black Cotton Soil, making it ideal for a wide variety of civil applications.

**Figure 3. Polypropylene Fibre Liang *et al.* (2020)**

Kota Stone Slurry

Kota Stone Slurry is a by-product generated during the cutting and polishing of Kota stone, a popular natural stone used in construction and flooring applications. This slurry, which consists of fine particles and water, is usually considered waste, and disposed of without realizing its potential as a resource. However, recent research and practical applications have shed light on the value and benefits of utilizing Kota Stone Slurry in various fields, including agriculture, soil improvement, and environmental conservation. Kota stone, known for its durability, attractive appearance, and resistance to wear and tear, is extensively quarried, and processed in regions where it is abundantly available. During the cutting and polishing processes, large amounts of slurry are produced, which traditionally were discarded as industrial waste, causing environmental concerns. However, recognizing the need for sustainable and eco-friendly practices, researchers and experts has started exploring the potential uses of Kota Stone Slurry to minimize its environmental impact and maximize its value. The composition of Kota Stone Slurry typically includes fine particles of stone, water, and trace amounts of chemicals used during the processing. These particles are predominantly composed of calcium carbonate and other minerals present in the stone. The slurry has a smooth, creamy consistency, making it suitable for various applications once its potential is harnessed. In recent years, studies and experiments have focused on utilizing Kota Stone Slurry in soil improvement projects, particularly in addressing problematic soils like Black Cotton Soil. Figure 4 shows the Kota Stone Slurry.

The unique properties of the slurry, such as its binding and stabilizing characteristics, make it an ideal candidate for enhancing soil stability, reducing erosion, and improving load-bearing capacity.



Figure 4. Kota Stone Slurry

The unique properties of the slurry, such as its binding and stabilizing characteristics, make it an ideal candidate for enhancing soil stability, reducing erosion, and improving load-bearing capacity. Moreover, the use of Kota Stone Slurry in agriculture has gained attention due to its potential as a soil amendment. The slurry's high calcium carbonate content can help neutralize acidic soils and improve pH levels, creating a Fly Ash vourable environment for plant growth. Additionally, the presence of trace minerals and micronutrients in the slurry can supplement the soil's nutrient content, promoting healthy plant development. The exploration of Kota Stone Slurry as a resource presents an opportunity to mitigate waste generation, reduce environmental pollution, and contribute to sustainable development practices. Recognizing the value of this by-product and finding innovative applications can transform what was once considered waste into a valuable resource with wide-ranging benefits.

Impact of Kota stone slurry on the Environment and Human

The mining sector has contributed to a variety of environmental issues due to poor waste management and inadequate planning (Mosaferi *et al.*, 2014). The total dissolved solids and sulFly Ash tes in the receiving water (Al-Joulani, 2014) rise when mining waste is placed in dry streams because the surface runoff (Jangid *et al.*, 2018b) takes it downstream. Garbage harms the environment because it raises soil alkalinity, making it unsuitable for plant development (Nasserdine *et al.*, 2009; Jain *et al.*, 2016).

When garbage is dumped on the ground for long periods, it could influence the availability of groundwater because the microscopic slurry particles hinder the flow of the water as it percolates down the aquifers (Karaca *et al.*, 2012; Wang and Gunasekaran, 2021). The accumulation of stone slurry owing to poor disposal practices also detracts

from the area's aesthetic attractiveness (Almeida *et al.*, 2007; Sarami and Mahdavian, 2016). Human health is negatively impacted when mining waste is dumped in excessive amounts. Incorporating this trash into the concrete production process has the potential to reduce the high operational costs associated with waste management and treatment (Zichella *et al.*, 2020).

Physical and Chemical Properties of Kota Stone Powder

Kota stone is found in many different colours and textures and is mostly a sedimentary rock. Stone deposits are layered and dispersed over well-formed weak planes, allowing for well-textured and smooth homogeneous panels of stone in varying thicknesses. Kota stone is a soft stone with a hardness of 3-4 (Mohr's scale). It has minimal porosity and high-water resistance, making it a perfect material for use in the construction of concrete buildings. Table 6 illustrates the physical characteristics of Kota Stone Slurry.

Table 6. Physical characteristics of Kota Stone Slurry

Authors	Water Absorption (%)	Colour	Specific Gravity
Chouhan <i>et al.</i> (2021)	7.23	White	2.59
Jangid <i>et al.</i> (2018)	15.6	Dirty Grey	2.35
Gautam <i>et al.</i> (2017)	23	White	2.81

The number of by-products created by the flaggy limestone industry during stone processing approaches 10-12 million tones every year. Water makes up most of the flaggy limestone, with just around 10% of flaggy limestone powder. Considering the magnitude of trash produced, there is an urgent need to reuse the rubble from stone construction projects to ensure the long-term viability and cost-effectiveness of the building industry. Table 7 presents t0068e Chemical Composition of Kota Stone Slurry.

Table 7. Chemical composition of Kota Stone Slurry

Authors	SiO ₂ (%)	Al ₂ O ₃ (%)	Fe ₂ O ₃ (%)	CaO (%)
Lakhani & Tomar (2014)	22.69	3.26	2.72	36.32
Hiren & Kumar Pitroda (2017)	26.67	2.20	-	38.86

Fly Ash

The burning of pulverized coal in thermal power plants produces Fly Ash as a by-product. It is a granular substance with particles ranging in size from submicron to 250 μm (Lee *et al.*, 2003). Fly Ash is interesting because its chemical composition, mineralogy, and reactivity vary greatly over its various particle sizes (Tiwari *et al.*, 2014). Fly Ash is favored over alternative materials in the manufacture of cement, concrete, and brick because of its pozzolanic property, tiny particle size, flow characteristic, and mix of crystalline and amorphous phases (Kumar *et al.*, 2007). FLY ASH has a variety of potential applications beyond that of simple filler material, including as a reactive component. The production of geopolymers is one such application in which FLY ASH might be used as an active participant in a process (Kumar *et al.*, 2015).

Physical and chemical properties of Fly Ash

Fine powdery particles that are generally spherical, solid, hollow, and amorphous makeup Fly Ash. The typical specific gravity of coal ashes is roughly 2.0; however, this value fluctuates widely. Particle form, gradation, and chemical makeup are only a few of the components that contribute to this diversity (Pandian *et al.*, 1998). Fly Ash could be categorized as sandy silt to silty sand depending on the distribution of their particle sizes. Most Indian coal ashes are silt-size, with a smaller percentage being clay-size (Pandian, 2004). The surface area and bulk density of Fly Ash are both rather high (Ram and Masto, 2014). Fly Ash could range in colour from orange to dark red, brown, or white to yellow, depending on the percentage of unburned carbon and iron present (Ahmaruzzaman, 2010; Bhatt *et al.*, 2019).

Fly Ash could be used in a variety of ways, but its classification and selection are both determined by its qualities. The fineness and Loss of Ignition (LOI) of the Fly Ash are important metrics to keep

an eye on throughout the selection process (Gamage *et al.*, 2011). In addition, distinct types of Fly Ash could be distinguished based on several additional physical and chemical characteristics. Coal type, mineral matter chemistry and mineralogy, furnace design, furnace operation, and particle control strategies (such as Sulphur Oxide (SOx) and Nitrogen Oxide (NOx) control technologies) all have an impact on the physical characteristics of the resulting Fly Ash (French and Smitham, 2007). Particle sizes for Fly Ash vary between 0.5 and 100 micrometers and are typically round. Researchers from a variety of fields have examined the Fly Ash physical characteristics in Table 8. Properties including workability, water demand, and permeability are affected by these characteristics in the finished product.

The chemical components of Fly Ash are almost identical to those of Portland cement, as shown in Table 9. The primary components of both Fly Ash and cement: Silica Oxide (SiO₂), Aluminum Oxide (Al₂O₃), Iron Oxide (Fe₂O₃), and Calcium Oxide (CaO) are chemically identical. Fly Ash (classes F and C) and Portland cement (class N) and natural pozzolan (class O) all include silica, although the relative amount of these compounds varies widely.

Portland cement has a high concentration of lime (CaO), while has a low concentration. Reactive silicates could be found in greater concentrations in than in Portland cement. Fly ash is suggested for use with Portland cement due to its pozzolanic activity, which leads to the formation of identical cementations compounds created by the hydration of Portland cement (see Figure 5) (Ichimaru Watanabe *et al.*, 2021). Pozzolanic reaction inhibits efflorescence, which is caused by free lime leaking out of treated concrete and gives strength at a similar time (Barden, 1972; Raju *et al.*, 2021).

Table 8. Physical properties of fly Ash

Property	Maher Balaguru (1993)	Mitash N (2007)	Huang <i>et al.</i> (1995)	Muhardi <i>et al.</i> (2010)
Specific Gravity	2.54	1.9-2.55	2.06	2.3
Moisture Content	13.60%		0.53%	19.75%
Fineness			13.80% in NO. 325	0.6-0.001mm
LOI			7.5	
Maximum Dry Density	1.65 g/cm ³	0.9-1.6 g/ cm ³		1.53 g / cm ³ cc
Uniformity Coefficient	2.5	3.1-10.7		
Liquid Limit	16.8			
Permeability	0.9 x 10 ⁻⁵ cm/s	10-5 - 10-3 cm/s		4.87 x 10 ⁻⁷ cm/s
Angle of Internal Friction		30°-40°		23°-41°
Cohesion		Negligible		3-34 kPa
Coefficient of Consolidation				0.1 - 0.5 m ² /year

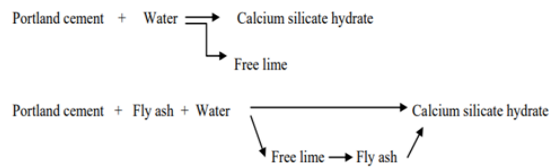


Figure 5. Reaction of fly ash in cement

Environmental Impact of Fly Ash

The utilization of for soil improvement in problematic Black Cotton Soil, in combination with dry Kota Stone Slurry, can have both positive and negative environmental impacts. It is important to consider these impacts to ensure sustainable and responsible practices. Here are some key points regarding the environmental impact of Fly Ash in this context:

1. Positive Environmental Impacts

- **Waste Utilization:** is a byproduct of coal combustion in power plants. By using for soil improvement, it reduces the amount of waste material that would otherwise be sent to landfills, promoting its beneficial reuse.
- **Reduced Soil Excavation:** The use of Fly Ash in soil improvement reduces the need for traditional soil excavation and replacement methods. This helps preserve natural landscapes, minimize habitat disruption, and reduce the consumption of resources associated with soil extraction.
- **Reduced Carbon Footprint:** FLY ASH has cementitious properties, which can reduce the need for energy-intensive materials like cement in soil stabilization. This substitution can lead to a reduction in greenhouse gas emissions associated with cement production, thus lowering the carbon footprint of construction projects.

2. Negative Environmental Impacts

- **Heavy Metal Contamination:** Fly Ash may contain trace amounts of heavy metals such as mercury, arsenic, and lead. If not properly managed and contained, these contaminants can leach into the soil and groundwater, posing a potential risk to ecosystems and human health. It is crucial to follow appropriate guidelines and regulations for the safe handling and disposal of Fly Ash to prevent such contamination.
- **Transportation Impact:** Fly Ash is often sourced from power plants located at a considerable distance from the construction site. Transporting large quantities of Fly Ash over long distances can

contribute to carbon emissions and air pollution. Minimizing transportation distances or considering alternative sources of Fly Ash can help mitigate this impact.

- **Environmental Monitoring:** Regular monitoring and quality control measures should be in place to ensure that the utilization of Fly Ash in soil improvement does not result in unintended adverse effects on the environment. This includes monitoring for any potential leaching of contaminants and assessing the long-term stability of the treated soil.

To mitigate the potential negative environmental impacts, it is essential to adhere to relevant regulations and guidelines governing the use of Fly Ash and dry Kota Stone Slurry. Implementing proper handling, storage, and disposal practices, along with rigorous monitoring, can help minimize any detrimental effects and ensure the sustainability of the soil improvement process (Hearn, 2019).

Conclusion

It has been discovered that dry Kota Stone Slurry, a by-product of Kota stone manufacturing, could be used as a binding agent to efficiently stabilize Black Cotton Soil. It strengthens the soil's cohesiveness, lessens its flexibility, and diminishes its tendency to shrink or swell. Fly Ash, a by-product of burning coal has great pozzolanic qualities that improve the soil's strength, durability, and load-bearing capacity. In the presence of water, Fly Ash reacts with calcium hydroxide to generate cementitious compounds that boost the engineering qualities of Black Cotton Soil. The combination of dry Kota Stone Slurry and Fly Ash creates a synergistic effect, amplifying the benefits of each material. The mixture produces a stable and compacted soil mass that resists swelling and shrinkage, exhibits improved shear strength, and provides a solid foundation for construction projects. This review indicates that the use of dry Kota Stone Slurry and Fly Ash for soil improvement in problematic Black Cotton Soil holds promise for enhancing its engineering properties and addressing its challenges. This approach offers a sustainable and cost-effective solution for soil stabilization, benefiting construction projects and the environment. Further study and field trials are recommended to validate and optimize the application of this technique in various scenarios.

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