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Stabilization of Black Cotton Soil by Using Coal Dust and Stone Dust

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A B S T R A C T

The stabilization of expansive soils like black cotton soil poses significant challenges in civil engineering projects due to their high susceptibility to volume changes. This study explores an innovative approach to address this challenge by utilizing coal dust and stone dust as stabilizing agents. These waste materials, abundant in coal mining and stone crushing industries, respectively, hold promise as cost-effective and environmentally sustainable solutions for soil stabilization. Through a combination of literature review and experimental investigation, this research evaluates the efficacy of coal dust and stone dust in stabilizing black cotton soil. Various parameters such as soil composition, particle size distribution, mixing ratios, compaction methods, and curing conditions are systematically studied to assess their influence on the stabilization process. The experimental results demonstrate that the addition of coal dust and stone dust significantly improves the engineering properties of black cotton soil, including its strength, compressibility, and durability. Moreover, the study investigates the long-term performance and environmental impact of the stabilized soil, providing insights into its suitability for engineering applications. This research contributes to the understanding of sustainable soil stabilization techniques and offers practical guidance for engineers and practitioners involved in civil engineering projects, particularly those dealing with expansive soils. The utilization of coal dust and stone dust not only provides a solution for stabilizing problematic soils but also contributes to the efficient management of industrial waste, promoting a circular economy and environmental sustainability.

Keywords: Soil, GSB, BCS, Subgrade, Civil

1. Introduction

Black cotton soil (BCS), a common clay-rich soil in dry regions, is a nightmare for pavements. It dramatically shrinks and swells with seasons, causing cracks and collapse. This research explores using coal dust and stone dust to stabilize BCS, making pavements more durable.

This part can be omitted as it's not directly relevant to the challenge of black cotton soil and the proposed solution. We can focus on the core issue: “Black cotton soil, a problematic subgrade material for pavements due to its shrinking and swelling, is the target for this research. We're exploring coal dust and stone dust as stabilizers to improve pavement durability.”

Problematic soils, like expansive clays, shrink and swell with seasonal moisture changes, causing pavement damage. This is especially prevalent in India, where a large portion of land is affected. Traditional soil stabilization uses binders or mechanical methods to improve strength and stability. This research explores using coal dust and stone dust as a potential solution for these problematic soils..[1], [2], [11]–[20],

One of the sources of weak or problematic soils is the generated from coal mining activities. Overburden (OB) burden is the material that lies above the coal seam and has to be removed to access the coal. Overburden consists of various types of rocks, soils, and minerals, which are often mixed and disturbed during the mining process. Overburden is usually dumped on the adjacent land in the form of external dumps, which occupy a large area and cause environmental problems, such as land degradation, groundwater contamination, erosion, and slope failure. The overburden dumps are also a waste of valuable land resources, which could be used for other purposes, such as agriculture, forestry, or recreation. One of the possible solutions to utilize the overburden dumps and improve their stability is to use them as a source of soil stabilization material. This can be done by mixing the overburden with another additive such as aggregate[10mm] or GSB material & other additives. By doing its stabilization we can enhance its physical and chemical properties.

1.1 Aim & Objectives

1. Investigate the influence of coal dust and stone dust on the mechanical properties of BCS

2. Develop an optimal mix design

3. Assess the environmental implications of using coal dust and stone dust

1.2 Materials

- Black cotton soil (Vaadgav area, chandrapur)
- Coal dust (obtained from a DRC Mine No. 03)
- Stone dust (From College Concreate Lab)
- Distilled water

BLACK COTTON SOIL (BCS) - Black cotton soil, a dark and fertile soil found in warm regions, is a boon for farmers. Its high clay content and excellent water retention make it ideal for growing cotton and other crops. However, this very characteristic becomes a challenge for construction - it shrinks and swells dramatically with seasonal moisture changes, causing problems for roads and buildings built on it.

COAL DUST - Coal dust isn't just dust! It's a complex mix of over 50 elements and their oxides, varying depending on particle size and coal source. Think of it as a fingerprint - unique for each coal seam. In mines, airborne dust is mostly coal particles, but can also contain bits of rock from the surrounding environment.

STONE DUST - Stone dust, leftover from crushing rocks, is basically like coarse sand. It's cheaper than regular sand and can be used in construction projects for similar purposes, providing good support.

Fig 1. Black Cotton Soil

Fig 2. Stone Dust

Fig 3. Coal Dust

2. Literature Review

1. ***.A. HOSSAIN, M KHANDAKER (2011***): I studied the cost of soil stabilization is high due to overdependency on the utilization of industrial additives such as cement, lime etc. So, by keeping soil stabilization economical the used of agricultural based product should be done. These agricultural based product also reduce environmental hazardous. In soil modification addition of a modifier (cement, lime etc.) which causes change in index properties, increase in strength, change durability. RHA stabilized the soil slowly when mixed with lime and gypsum.
2. ***SINGH ET AL. (2016)*** : Several research efforts have investigated the utilization of industrial byproducts for BCS stabilization. I explored the effectiveness of fly ash, another coal combustion byproduct, in stabilizing BCS. Their findings indicated a significant improvement in strength and a reduction in swelling potential with the incorporation of fly ash

3. Methodology

This experimental study investigates the effectiveness of coal dust and stone dust in stabilizing black cotton soil (BCS) for pavement subgrade construction. These readily available byproducts hold promise as a cost-effective and eco-friendly alternative to traditional stabilizers, potentially improving the long-term performance and sustainability of pavements built on challenging BCS terrain.

Phase 1: Characterization of Plain BCS

Sample Collection - Black cotton soil samples will be collected from a designated location following established protocols to ensure a representative sample. This might involve collecting soil from multiple locations within the designated area and homogenizing them to minimize variations.

Physical Property Tests - A series of standard tests will be conducted on the collected BCS to characterize its physical properties. These tests will include:

Atterberg Limits - This suite of tests determines the liquid limit, plastic limit, and plasticity index of the BCS. These parameters provide valuable insights into the soil's workability, shrink-swell potential, and overall plasticity characteristics.

Specific Gravity: This test measures the density of the soil particles themselves, excluding the pore spaces. It serves as a benchmark for evaluating the effectiveness of stabilizers in altering the overall density of the stabilized BCS.

Free Swell Index: This test quantifies the potential of the BCS to swell upon saturation with water. This information is crucial for understanding the challenges associated with volume changes in the subgrade due to seasonal moisture variations.

Compaction Test: This test, typically conducted according to ASTM D6913 (Standard Test Method for Compacted Soil-Lime Mixtures for Use in Construction and Similar Purposes), will determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the BCS

California Bearing Ratio (CBR) Test: This test, following ASTM D1883 (Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils), will assess the load-bearing capacity of the un-stabilized BCS.

Phase 2: Evaluation of Coal Dust and Stone Dust Stabilization

•Material Preparation: Coal dust and stone dust samples will be obtained from reliable sources. Particle size distribution will also be determined using sieving techniques.

•Mix Design: Based on a review of previous research and preliminary trials to optimize performance, varying proportions of coal dust and stone dust will be selected for mixing with the BCS. This might involve using individual percentages of each dust type or a combined dust blend (2%, 4%, 6%).

•Compaction: Prepared soil-dust mixtures will be compacted at their respective OMCs, previously determined in Phase 1. A compaction mould and compactor complying with relevant ASTM or AASHTO standards will be used to achieve consistent compaction effort across all specimens.

•CBR Testing: This will allow for direct comparison of the load-bearing capacity of the stabilized BCS with the un-stabilized control specimens from Phase 1. The primary test series will involve individual additions of coal dust and stone dust at varying percentages (e.g., 2%, 4%, and 6%) to evaluate their independent effects

Phase 3: Results

This section will present the findings from the experimental program, including:

- The effect of coal dust and stone dust on the Atterberg limits of BCS, indicating changes in plasticity and workability.
- The relationship between stabilizer content, OMC, and MDD, identifying the optimum conditions for compaction.
- The influence of stabilization on the CBR values, reflecting the improvement in strength and load-carrying capacity.
- The impact of coal dust and stone dust on the swelling potential of BCS, signifying the effectiveness in reducing volume change.

Phase 4: Conclusion

•Based on the experimental findings, the study will draw conclusions regarding the effectiveness of coal dust and stone dust in stabilizing BCS for pavement subgrade applications. The optimal dosages for each stabilizer or their combination will be recommended.(Barsagade et al. 2024)

4. Results

Test performed on black cotton soil

Table No. 1 Properties of Black Cotton Soil

Properties	**Black cotton soil**
Specific gravity	2.461
Liquid limit	29.57%
Plastic limit	70.59%
Plasticity index	41.22 %
Free swell index (%)	80%
Maximum dry density	1.54 g/cc
Optimum moisture content	24.76 %
California bearing ratio test	2.26

Test perform on Soil with admixture –

- SPCT
- CBR

Soil with coal Dust:

Table No. 2 OMC, MDD and CBR of Soil with Coal Dust (2%,4%,6%)

Sr no.	Percentage (%)	Optimum Moisture Content	Maximum Dry Density	California Bearing Ratio Test
1.	2%	21.775 %	1.657 g/cc	2.42
2.	4%	20.272%	1.560 g/cc	2.58
3.	6%	25.162%	1.433g/cc	2.66

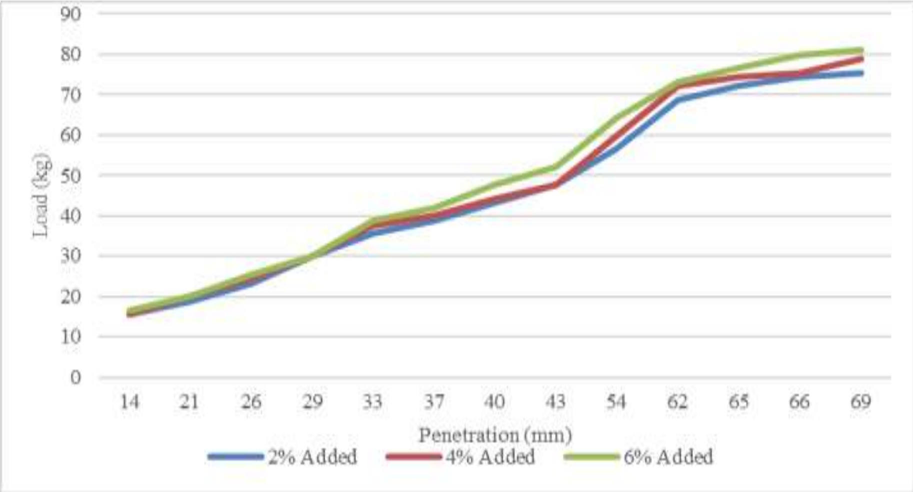

Fig 4. California Bearing Ratio of Soil with Coal Dust

Soil with Stone Dust:

Table No. 3 OMC, MDD and CBR of Soil with Stone Dust (2%,4%,6%)

Sr no.	**Percentage (%)**	**Optimum Moisture Content**	**Maximum Dry Density**	**California Bearing Ratio Test**
1.	2%	24.470%	1.596g/cc	2.58
2.	4%	22.424%	1.554g/cc	2.74
3.	6%	19.697%	1.527g/cc	2.83

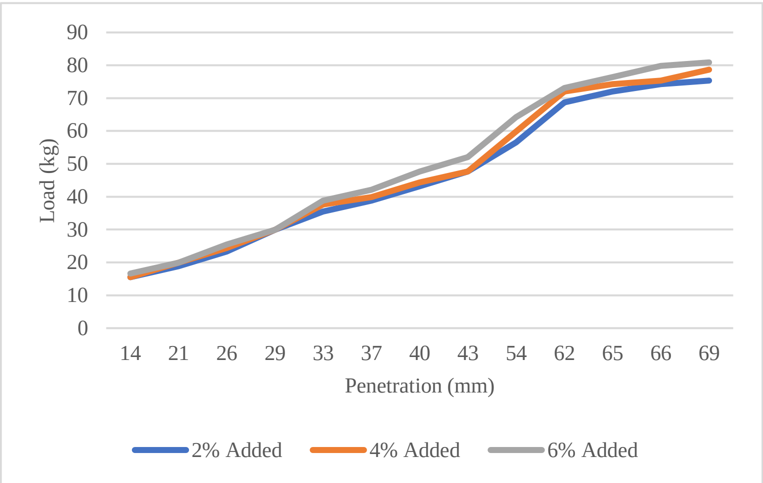

Fig 5. California Bearing Ratio of Soil with Coal Dust

5. Conclusion

By doing this experimental study we investigated the potential of coal dust and stone dust as stabilizers for black cotton soil (BCS) in pavement subgrade construction. Through a series of laboratory tests, the impact of these additives on the engineering properties of BCS was evaluated, aiming to improve its suitability for pavement subgrades.

Impact of coal dust:

The results from the experimental study indicated that coal dust can have a limited positive effect on some properties of BCS. The addition of coal dust may lead to slight improvements in:

- Studies have shown that adding up to a certain percentage of stone dust can significantly increase the California Bearing Ratio (CBR) of BCS, indicating a clear improvement in its load-bearing capacity.
- Experiments have shown that also adding up to a certain percentage of stone dust can significantly increase the optimum moisture content that normal black cotton soil.

Impact of stone dust:

The addition of stone dust to black cotton soil generally demonstrated a more positive and consistent improvement across various engineering properties:

- Stone dust can dilute the clay content in BCS, reducing its plasticity and susceptibility to volume changes with moisture variations. This translates to improved stability and reduced potential for cracking in the pavement subgrade.
- Studies have shown that adding up to a certain percentage of stone dust can significantly increase the California Bearing Ratio (CBR) of BCS, indicating a clear improvement in its load-bearing capacity.

GENERAL CONCLUSION:

Based on the findings of this research, stone dust emerges as a more promising and reliable stabilizer for black cotton soil compared to coal dust for pavement subgrade applications. Stone dust offers a more predictable improvement in strength, reduces the negative effects of clay's plasticity, and poses less of an environmental concern. In conclusion, this study provides a comprehensive investigation into the effectiveness of waste coal overburden (WCL) in stabilizing soil for engineering applications. By reviewing existing literature and presenting experimental findings, it has been demonstrated that WCL overburden holds significant potential as a sustainable soil stabilizer. The research highlights various factors influencing the stabilization process and emphasizes the positive impact of incorporating WCL into the soil on its strength, durability, and resistance to environmental factors. Furthermore, the economic and environmental benefits associated with the utilization of WCL overburden have been underscored. This study contributes valuable insights for engineers and policymakers, promoting the adoption of WCL overburden as a viable solution for soil stabilization while addressing both engineering requirements and environmental concerns. [1],

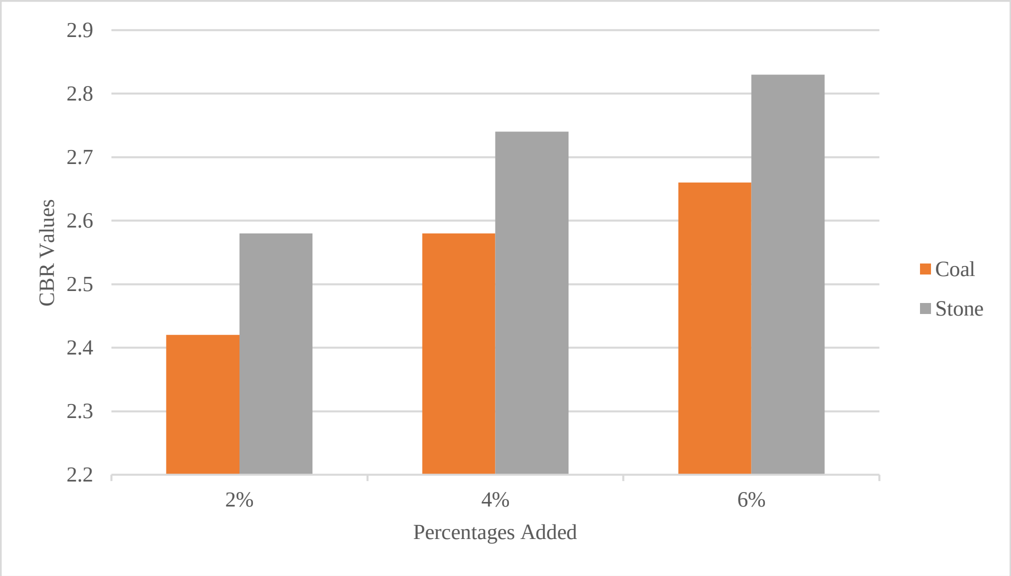

Fig 6 : Graph Shows Stone dust showing more results than coal dust.

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