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Use of Bottom Ash in Improving the Strength Characteristics of Black Cotton Soil

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Abstract

Expansive soils, such as black cotton soil, cover approximately 20% of the total land area in India, predominantly in states like Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, and Tamil Nadu. These soils are characterized by their high swelling and shrinkage behaviour, which is exacerbated by hot climatic conditions and poor drainage. Such properties make expansive soils highly problematic for construction, leading to frequent failures in structures like buildings, bridges, railway embankments, and highway pavements. This study explores the use of bottom ash, a by-product of coal combustion, as a stabilizing agent to improve the engineering properties of expansive soils. Laboratory experiments were conducted by mixing bottom ash with black cotton soil at varying proportions (0% to 100%). The geotechnical properties, including compaction characteristics (OMC and MDD), California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS), were determined. The results indicate that the addition of bottom ash significantly enhances the strength and stability of the soil. The optimum percentage of bottom ash was found to be 40% for UCS and 50% for CBR. The study concludes that bottom ash is an effective, sustainable, and eco-friendly material for stabilizing expansive soils, making them more suitable for construction purposes.

Keywords: Expansive soil, black cotton soil, bottom ash, soil stabilization, OMC, MDD, CBR, UCS.

1. Introduction

Expansive soils, particularly black cotton soil, are a significant concern in civil engineering due to their high swelling and shrinkage characteristics. These soils are prevalent in regions with hot climates and poor drainage, such as parts of India, including Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, and Tamil Nadu. The swelling and shrinkage behavior of these soils can cause severe damage to structures, including buildings, bridges, and highway embankments, leading to substantial economic losses.

Soil stabilization is a widely used technique to mitigate the problems associated with expansive soils. Traditional stabilizers like lime and cement have been effective, but their high cost and environmental impact have led to the exploration of alternative materials. Bottom ash, a by-product of coal combustion in thermal power plants, has shown promise as a stabilizing agent due to its pozzolanic properties and availability as an industrial waste material.

This study investigates the potential of bottom ash in improving the strength characteristics of black cotton soil. The geotechnical properties of the soil, including compaction characteristics, CBR, and UCS, were evaluated at varying proportions of bottom ash.

2. Literature Review

Studies Using Ceramic Waste:

Al-Jabri, K. S., Al-Saidy, A. H., & Al-Shihri, F. (2009).

Use of industrial by-products for soil stabilization: A review of the potential applications of bottom ash in soil stabilization.

Journal of Materials in Civil Engineering, 21(4), 249–257. This paper reviews various industrial by-products, including bottom ash, and discusses their application in soil stabilization**.**

Madhav, M. R., & Somashekar, A. (2004).

Use of industrial by-products for improving soil properties.

Geotechnical Engineering Journal of the SEAGS & AGSSEA, 35(2), 37–43. This paper covers the use of industrial by-products, including bottom ash, in improving soil properties, such as strength and shrinkage.

Kumar, A., & Parida, M. (2014).

Effect of bottom ash on the behaviour of expansive soil.

International Journal of Civil and Structural Engineering, 4(3), 515–522.This research paper investigates the influence of bottom ash on the compaction and shear strength characteristics of expansive soils like black cotton soil.

Zakir Hossain, M., & Hossain, S. (2017).

Improvement of black cotton soil using bottom ash for subgrade applications.

Advances in Civil Engineering, 2017, 1–7.This study explores how the addition of bottom ash enhances the performance of black cotton soil in road construction and subgrade applications.

Sivapragasam, C., & Subramanian, K. (2012).

Utilization of coal bottom ash as a soil stabilizer.

Geotechnical Testing Journal, 35(5), 1–12. The paper discusses various aspects of bottom ash as a soil stabilizer, including improvements in compaction, strength, and durability.

3. Selection of Materials

Black Cotton Soil: The soil sample was collected locally and classified as CH (high plasticity clay) according to the Unified Soil Classification System (USCS).

The soil was tested for its basic properties, including Atterberg limits, consistency indices, and swell characteristics.

Bottom Ash: Bottom ash, a by-product of coal combustion, was collected from a thermal power plant. It is composed of silica, alumina, and iron, with small amounts of calcium, magnesium, and sulfate.

The grain size of bottom ash typically ranges from fine sand to gravel.

4. Methods

The following tests were conducted to evaluate the geotechnical properties of the soil-bottom ash mixtures:

Compaction Test (IS 2720 Part 7): The compaction characteristics, including Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), were determined using the modified Proctor test. The soil was compacted in five layers, each subjected to 25 blows with a 4.89 kg rammer dropped from a height of 450 mm.

California Bearing Ratio (CBR) Test (IS 2720 Part 16): The CBR test was conducted to evaluate the strength of the soil-bottom ash mixtures. The CBR value was determined at different percentages of

bottom ash (0% to 100%).

Unconfined Compressive Strength (UCS) Test (IS 2720 Part 10): The UCS test was conducted to determine the compressive strength of the soil-bottom ash mixtures. The UCS values were measured at different percentages of bottom ash.

5. Results and Discussions

5.1 Compaction Characteristics

The compaction characteristics of the black cotton soil were significantly influenced by the addition of bottom ash. The OMC and MDD values decreased with an increase in the percentage of bottom ash. This reduction is attributed to the coarser texture of bottom ash, which reduces the water-holding capacity of the soil.

Table 1. Variation of OMC MDD of black cotton soil increased percentage of bottom Ash Added

%OF BOTTOM ASH ADDED	COMPACTION CHARACTERISTICS	
	OMC (%)	MDD(g/cc)
0	24.5	1.60
10	24.0	1.58
20	23.2	1.55
30	22.3	1.50
40	21.0	1.44
50	19.8	1.38
60	18.5	1.34
70	17	1.28
80	16.0	1.20
90	14.8	1.15
100	14.0	1.10

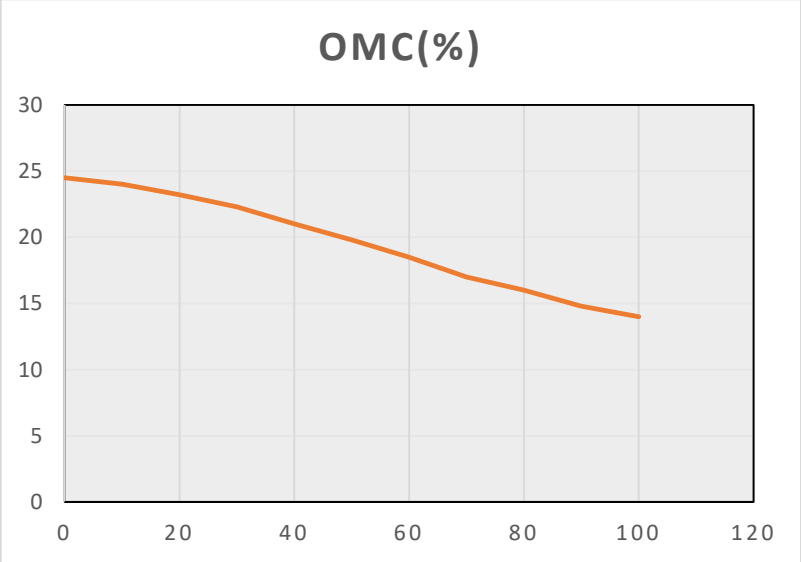

Fig 1: Variation of OMC in Black Cotton Soil

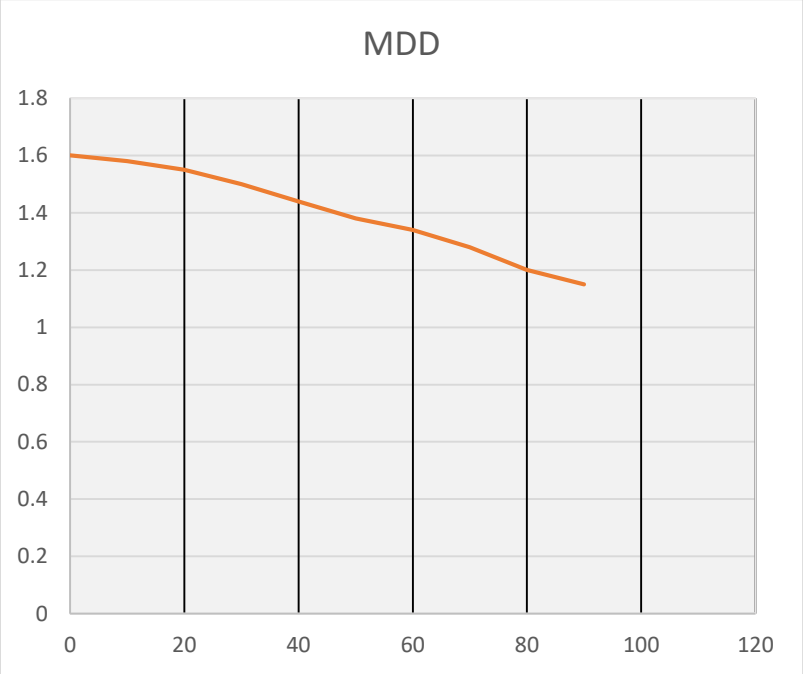

Fig 2: Variation of MDD in Black Cotton Soil

- The figure 1 shows the variation of OMC of the black cotton soil with increased percentages of bottom ash.
- The figure 2 shows the variation of MDD of the black cotton soil with increased percentage of bottom ash.

5.2 California Bearing Ratio (CBR)

The CBR values of the soil increased with the addition of bottom ash up to 50%. Beyond this percentage, the CBR values started to decrease. The optimum CBR value was observed at 50% bottom ash content, indicating that bottom ash significantly improves the load-bearing capacity of the soil.

Table 2. Variation of CBR Values with increases percentage of bottom Ash

% OF BOTTOM ASH ADDED	CBR(%)
0	2.0
10	3.0
20	4.0
30	5.5
40	7.0
50	8.5
60	7.5
70	6.5
80	6.0
90	5.5
100	5.0

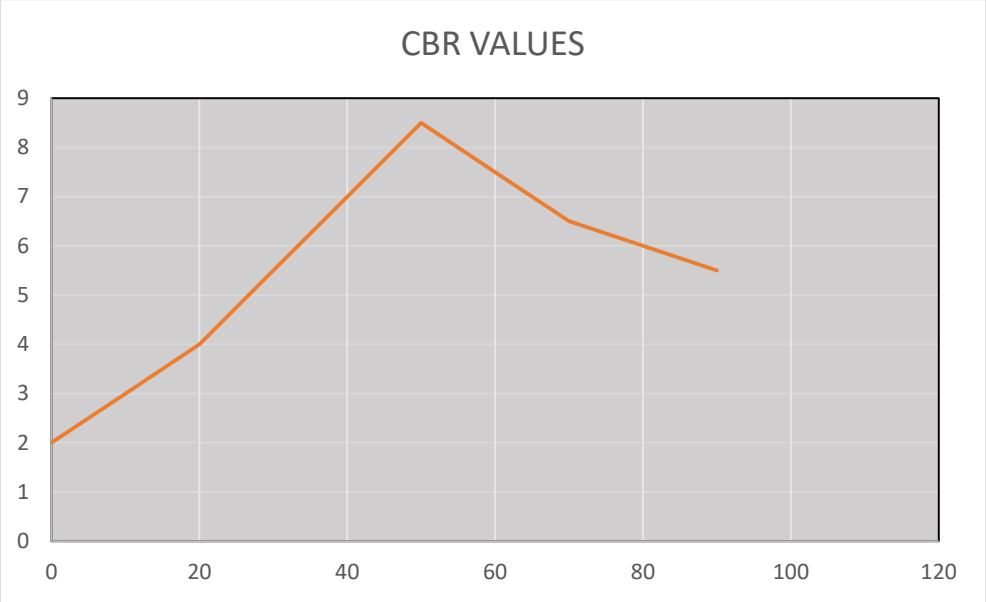

Fig 3: Variation of CBR Value with increased % of bottom Ash

5.3 Unconfined Compressive Strength (UCS)

The UCS values of the soil increased with the addition of bottom ash up to 40%. Beyond this percentage, the UCS values started to decrease. The optimum UCS value was observed at 40% bottom ash content, indicating that bottom ash enhances the compressive strength of the soil.

Table 3. Variation of UCS Values with increases percentageS of bottom Ash

% OF BOTTOM ASH	UCS(KN/M$^{2)}$
0	**150**
10	**165**
20	**190**
30	**220**
40	**250**
50	**210**
60	**150**
70	**-**
80	**-**
90	**-**
100	**-**

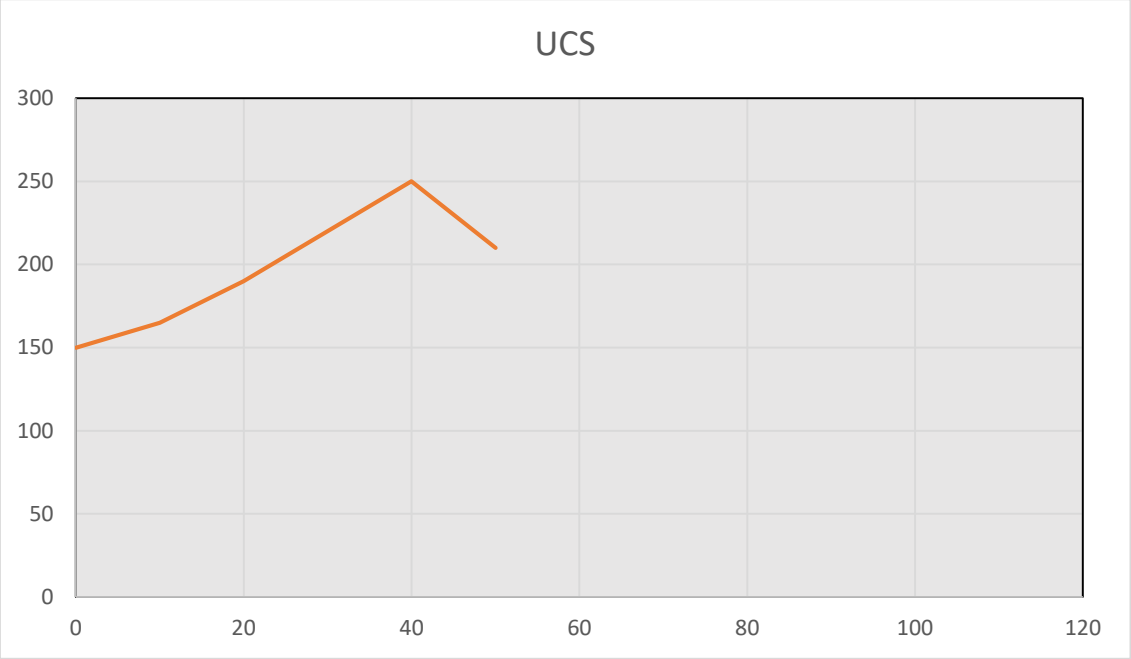

Fig 4: Variation of UCS Value with increased % of bottom Ash

6. Conclusions

The study demonstrates that bottom ash is an effective stabilizing agent for improving the strength characteristics of black cotton soil.

The addition of bottom ash significantly enhances the CBR and UCS values of the soil, with optimum performance observed at 50% and 40% bottom ash content, respectively.

The reduction in OMC and MDD values indicates that bottom ash improves the compaction characteristics of the soil, making it more suitable for construction purposes.

The use of bottom ash not only provides a sustainable solution for soil stabilization but also offers an eco-friendly approach to managing industrial waste**.**

7. References

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