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Experimental Study on The Stabilization of Black Cotton Soil Using Bottom Ash

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Abstract

Black cotton soil, a type of soil commonly found in India, is known for its ability to expand and absorb water during the monsoon season. Bottom Ash which is a byproduct of thermal power plants is utilized to stabilize expansive Black cotton soil which is generally disregarded for construction activities. The Atterberg limits and other engineering characteristics are determined to find out the ideal percentage of addition of Bottom Ash to achieve maximum shear strength of the black cotton soil.

Keywords: Black cotton soil, Bottom Ash, Atterberg limits

1. Introduction

Inorganic clays with a compressibility range of medium to high make up a prominent and important soil group in India. High properties of shrinking and swelling set them apart. Black Cotton soil makes up around 20% of India's total land area, or about 2,00,000 square miles, and is primarily found in the country's central and western regions. In this kind of soil, cotton is a significant crop that is raised. Although this soil has a low phosphorus level, it is rich in calcium carbonate, potash, lime, and magnesium carbonate. The majority of its locations are in states like Gujarat, Madhya Pradesh, and Maharashtra. The process of strengthening the many engineering characteristics of black cotton to create stable soil is known as soil stabilization. Controlled compaction, proportioning, and the inclusion of the appropriate admixtures and stabilizers are methods that can be used to achieve this [4]. In many locations, black cotton soil prevents the construction of roads. For a variety of construction projects, such as paving roads and building foundations, soil stabilization is crucial since it enhances the engineering qualities of black cotton soil.

2. Materials Used

2.1 Black Cotton Soil

The soil sample has been collected from Raichur district, Karnataka. The black cotton dirt was transported in sacks to the lab. To ascertain the soil's natural moisture content, a tiny sample was obtained, sieved through a 400 mm sieve, weighed, and then allowed to air dry before being reweighed [2].

Table 1: Properties of Black cotton soil

	Specific Gravity	Free swell index	Maximum Dry density (MDD)	Optimum moisture content
Black cotton soil	2.23	90%	1.77 g/cc	15%

2.2 Bottom ash

Bottom ash is a waste product that is collected from the gases coming from coal-fired furnaces, often of a thermal power plant. Bottom ash is the mineral residue that remains after coal is burned. These bottom ashes are collected by the power plants' Electro Static Precipitator (ESP). Bottom ashes are microscopic particles mostly made of alumina, silica, and iron. Bottom ash particles often have spherical shapes, which makes it simple for them to mix and flow to create an appropriate combination [5]. The minerals found in bottom ash are both amorphous and crystalline in form. Although its composition varies according to the type of coal used in the burning process, it is essentially a non-plastic silt. Bottom ash was procured from Raichur Thermal Power plant (KPCL), Karnataka. This bottom ash was sieved using a 2 mm sieve to remove the plant and foreign particles. For around 24 hours, the samples were dried in the oven.

Table 2: Properties of Bottom Ash

	Specific Gravity	Free swell index	Maximum Dry density (MDD)	Optimum moisture content
Bottom Ash	2.35	15%	1.58 g/cc	18%

3. Experimental Analysis

This experimental project was performed by adding bottom ash to black cotton soil in order to enhance its engineering characteristics. Different proportions of bottom ash were added to the black cotton soil; test specimens were produced and evaluated for their basic properties and requirements. The experimental analysis was carried out initially without any addition of bottom ash to the black cotton soil followed by 10%, 20%, 30%, 40%, and 50% addition [1]. The Unconfined compression test (UCC), Modified Proctor test and the Atterberg tests namely the liquid limit and plastic limit test were performed on different soil mixtures[6][7]. The results were inferred by comparing the results obtained for various test proportions.

3.1 Tests on Black Cotton Soil

Tests were conducted on black cotton soil obtained directly from the field. Preliminary tests were conducted namely the Specific gravity test by density bottle method, Wet sieve analysis, free swell index test, and tests to find out Atterberg limits according to Indian standard specifications. The table below shows the obtained results with their respective IS codes and permissible limits.

Experiment	Results	Permissible limits	IS codes
Specific gravity	2.23	2.6 to 2.7	IS-2720 (Part-3), 1980
Wet sieve analysis	Sand- 27.6% Silt/Clay-72%	-	IS-2720 (Part-4), 1980
Free swell index	90%	>50%	IS-2720 (Part-40), 1977
Maximum dry density	1.48 g/cc	1.2 g/cc to 1.8 g/cc	IS-2720 (Part-7), 1980
Optimum moisture content	25.80%	20% to 30%	IS-2720(Part-7),1980/ 1987
Liquid limit	67.02%	40% to 100%	IS-2720 (Part-5), 1985
Plastic limit	23.11%	20% to 65%	IS-2720 (Part-5), 1985
Plasticity index	43.91%	20% to 60%	IS-2720 (Part-5), 1985
UCC test	3.9 kgf/cm^2	-	IS-2720 (Part-10), 1973

Table 3: Test results for untreated Black cotton soil

3.2 Atterberg limits and Unconfined Compression test (UCC)

The liquid limit, plastic limit, and UCC tests were conducted to determine the characteristics of black cotton soil as obtained from the field and after the addition of the bottom ash [6][7]. The Plastic index was calculated using the equation (1).

Plasticity index = Liquid limit – Plastic limit (1)

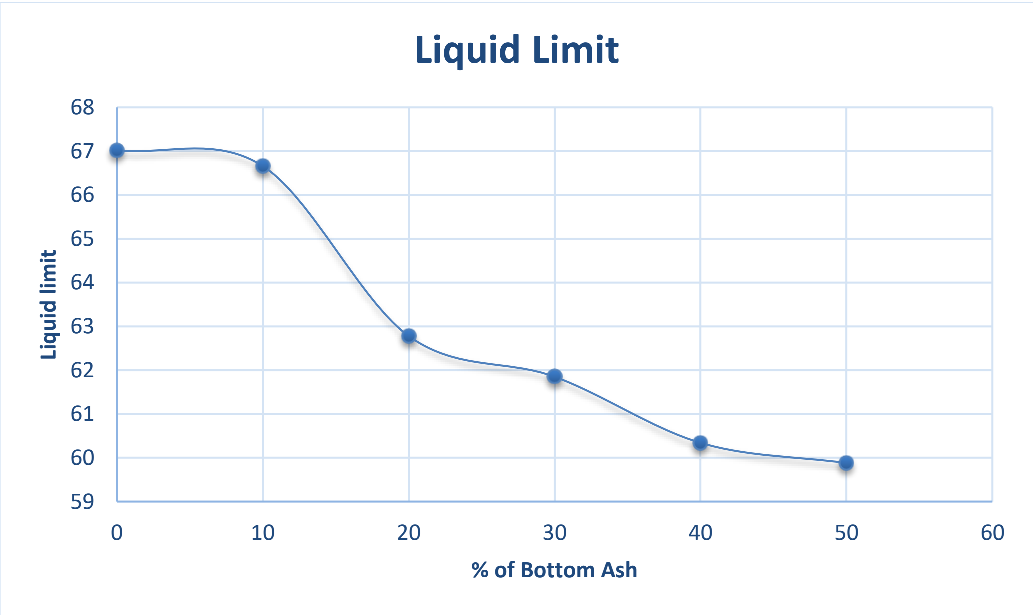
Table 4: Test results for different percentages of Bottom Ash addition

	Liquid limit (%)	Plastic limit (%)	Plasticity index	UCC test (kgf/cm^2)
0% ash	67.02	23.10	43.91	3.90
10% ash	66.66	25.92	40.70	2.79
20% ash	62.78	29.44	33.26	2.88
30% ash	61.85	29.54	32.26	1.73
40% ash	60.34	24.57	35.73	3.87
50% ash	59.88	29.41	30.39	5.06

After performing the tests, the liquid limit showed a decreasing trend with 59.88% at 50% addition of bottom ash. On the other hand, the plastic limit showed an increase with minor fluctuations.

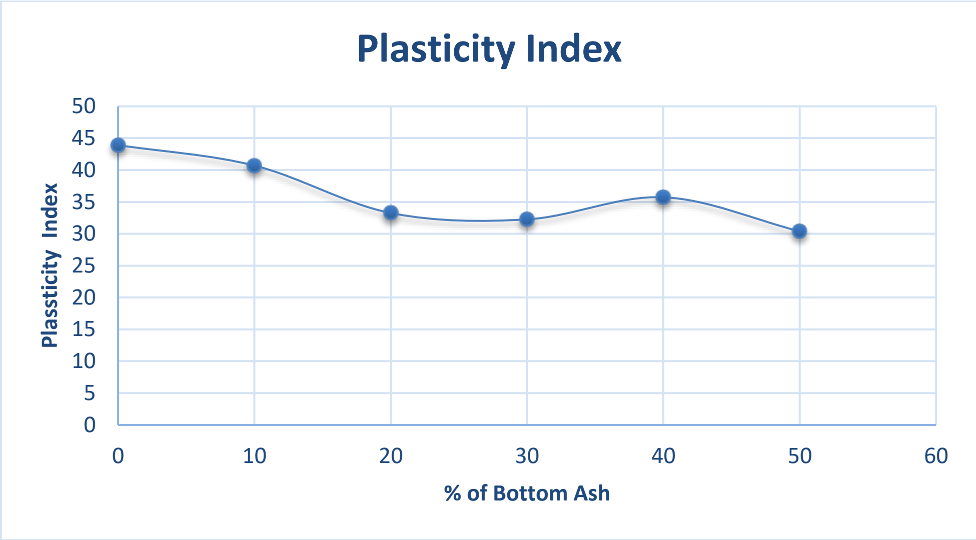
Figure 1 depicts the downward trend of the liquid limit from 67.02% to 59.88% at 0% and 50% addition of bottom ash respectively.

Figure 1: Percentage of Bottom Ash and Liquid limit comparison



The plasticity index values for varying test mixtures depicting a decline in values are shown in Figure 2.

Figure 2: Percentage of Bottom Ash and Plasticity index comparison



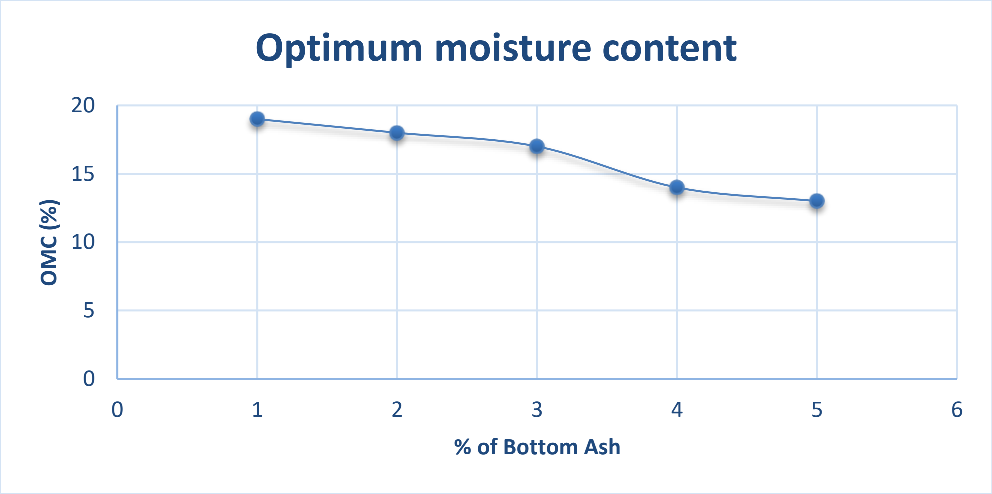
3.3 Modified Proctor Test

The Modified Proctor test was conducted in accordance with IS-2720, (Part-8),1980/1987. The permissible limit of optimum moisture content is 20% to 30% and maximum dry density is 1.2 to 1.8g/cc. The Optimum moisture content and maximum dry density are obtained for different percentages of bottom ash-black cotton soil mixtures.

Table 5: Test results for different percentages of Bottom Ash addition

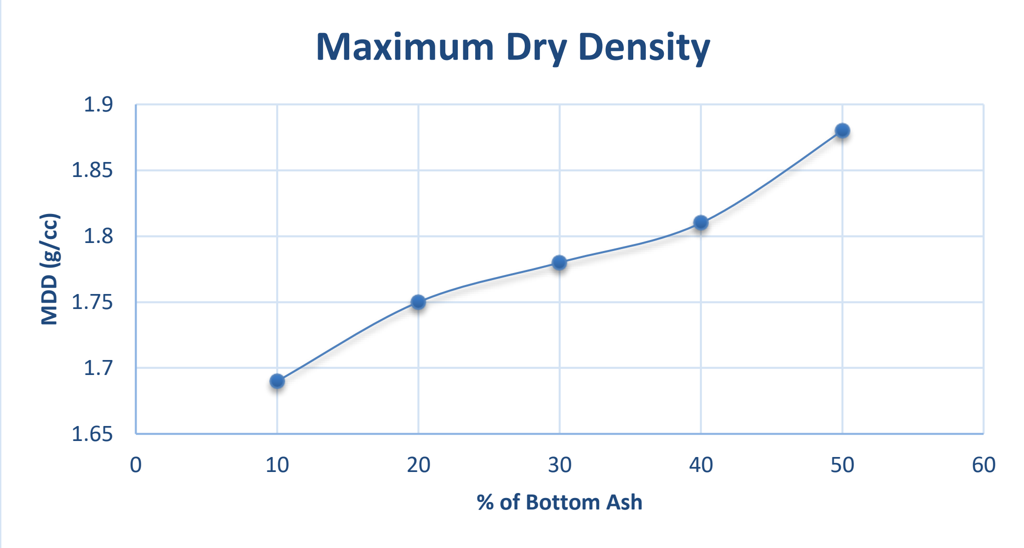
	Optimum Moisture content (%)	**Maximum Dry Density (g/cc)**
10% ash	19	1.69
20% ash	18	1.75
30% ash	17	1.78
40% ash	14	1.81
50% ash	13	1.88

Figure 3: Percentage of Bottom Ash and Optimum moisture content comparison



The increase in bottom ash quantity has decreased in optimum moisture content and increased the dry density from 1.69 g/cc to 1.88 g/cc for 10% and 50% addition respectively. The changes are represented in Figure 4.

Figure 4: Percentage of Bottom Ash and Maximum Dry Density comparison



4. Conclusion

The present project can serve as an effective method to utilize bottom ash in the stabilization of black cotton soil. All the basic tests were conducted on various soil–bottom ash mixes and conclusions were drawn based on these tests carried out. The plasticity index characteristics of expansive soil are diminished by the inclusion of bottom ash. With the incorporation of bottom ash, the liquid limit decreases, the plastic limit increases, and the overall plasticity index decreases. The unconfined compressive strength is enhanced by the addition of bottom ash. The values obtained from the unconfined compression test fall within the acceptable range for construction purposes. Based on the experiments performed, it can be concluded that a 50 % addition of bottom ash to the black cotton has a significant impact on the shear strength characteristics of the soil compared to other proportions.

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