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Effect of Coal Ash in the Stabilization of Expansive Soil for the Pavement

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Abstract: Construction and subsequent maintenance of pavements in good condition has become quite problematic especially in areas where soft or expansive soils are available below the sub grade. During rainy season the natural sub grade soils become soft and pose serious problem, strengthening of sub grade soil appear to be the only solution for keeping the pavement of surfaces serviceable.
In this paper, laboratory tests were conducted to find the index and engineering properties of soil with addition of coal ash. Index properties of the soil include liquid limit, plastic limit, shrinkage limit, grain size analysis and specific gravity tests. Strength tests related to Unconfined Compressive Strength and CBR were also conducted on the virgin expansive soil and the expansive soil mixed with different percentages of coal ash ranging from 0% to 60% in increments of 10%.
Keywords: Expansive soil, Coal ash, UCC, CBR.

1. Introduction

Expansive soils are popularly called as Black cotton soils in India subjected to lot of swelling and shrinkage characteristics. Structures constructed on these soils have been facing differential settlements resulting severe damages. Some of them are cracks in buildings, heaving of canals, failure of retaining structures and roads in many parts of India. Many attempts have been made after the properties of expansive soils of these areas to meet the different tasks, the popular Techniques removing partly/fully these expansive soils and foundation medium with a desirable one. Therefore stabilization is one of such attractive methods. Expansive soils are also referred to as “black cotton soil” in some parts of the world. They are so named because of their suitability for growing cotton. Black cotton soils have varying color, ranging from light grey to dark grey and black. The mineralogy of this soil is conquered by the presence of montmorillonite which is characterized by large volume change from wet to dry seasons and vice versa. Deposits of black cotton soil in the field show a general pattern of cracks during the dry season of the year. Cracks measuring 70 mm wide and over 1 m deep have been observed and may extend up to 3m or more in case of high deposits .The three most commonly used stabilizer for expansive clays are bitumen, lime and cement (1-5).

Researchers attempted to stabilize this soil have reported that the stabilization of this soil with bitumen, lime or cement is effective. Unfortunately, the costs of these stabilizers are on the high side making them economically unattractive as stabilizing agents. Recent trend in research works in the field of geotechnical engineering and construction materials focuses more on the search for cheap and locally available materials such as industrial wastes as stabilizing agents for the purpose of full or partially replacement of traditional stabilizers. Industrial waste is increasingly becoming a focus of researchers because of the enhanced pozzolanic capabilities of such waste when oxidized by burning. Thus, this study is aimed at evaluating the possibility of utilizing industrial wastes in the stabilization of black cotton soils. Addition of coal ash to Expansive soil is one such attempt to understand the possible mechanism governing the behavior of expansive soils-Coal ash mixes. Coal ash is an industrial waste obtained from thermal power plants by burning of coal. Coal ash consists of bottom ash (5-15%) and fly ash (85-95%). In India these plants produce 130MT Coal ash as a waste product. Therefore bulk stabilization of Coal ash becomes very essential in view of huge producing and to reduce the disposal areas under Environmental concerns. Utilization in Geotechnical applications are Sub grades, Embankment Materials, Backfill and Structural Materials (1, 5, 6, 8, 10, 12).

2. Methodology

This explains about the works carried out in this study .The effect of Industrial and Agricultural wastes such as Fly ash and Bottom ash under equal proportioning in the sub grade of flexible pavement system were studied.

2.1 Soil sample collection

Representative soil sample was collected from Cheranmaanagar, Coimbatore, tamilnadu state, India at the location 11.057˚, 77.019˚.The soil sample used for analysis is clay.

2.2 Material collection

Industrial wastes such as Coal ash is the materials collected for this study. Coal ashes were collected from Neyveli Lignite Corporation (NLC) Ltd, Neyveli, tamilnadu state, India.

2.3 Tests on materials

Laboratory test were conducted in the Geotechnical laboratory with the collected soil sample to classify the soil, to evaluate its physical and engineering properties and to study the compaction characteristics. Proctor’s Compaction tests, UCC tests, CBR (unsoaked and soaked) tests were conducted on samples under equal proportioning with 0%, 10%, 20%, 30%,40%,50% and 60%of Fly ash + Bottom ash combinations. The Standard Proctor’s Compaction tests were conducted on the soil samples to evaluate the Optimum Moisture Content and Maximum dry unit weight of samples. UCC tests were conducted on soil samples to determine the UCC strength and cohesion. The samples were also analyzed for the CBR value under both unsoaked and soaked condition. Results obtained were compared. Conclusions were made based on the results obtained.

3. Laboratory Investigation

This chapter elaborates the various physical and engineering properties of sub grade soil namely natural moisture content, specific gravity, liquid limit, plastic limit, shrinkage limit, grain size distribution, optimum moisture content, maximum dry density ,unconfined compressive strength and CBR Along with the mineral composition of Coal ash. All the tests were carried out as per IS codes.

3.1 Properties of sub grade soil

The properties of the sub grade soil were determined by conducting various laboratory tests and the results are presented in table 1.

4. Experimental Study

The experimental study involves Standard Proctor’s Compaction tests, Unconfined Compressive Strength test and California Bearing Ratio tests on soil sample with varying percentage under equal proportioning of Fly ash + Bottom ash combinations.

4.1Standard Proctor’s Compaction tests

Standard Proctor’s Compaction tests is conducted on soil samples under equal proportioning with 0%, 10%, 20%, 30%, 40%, 50% and 60% of Fly ash + Bottom ash combinations to determine the optimum moisture content and maximum dry density of soil sample. The optimum moisture content and maximum dry density of soil under equal proportioning with varying percentage of Fly ash+ Bottom ash combinations are reported in Table.2

Table.1Properties of Sub grade soil summary

Sl.No	Properties	Result	Remarks
1.	Initial Moisture Content	7.2	-
2.	Specific Gravity	2.71	-
3.	Grain Size Distribution % of Gravel % of Sand % of Clay % of Silt	 2.1% 30.5% 22.1% 45.3%	-
4.	Free Swell Index	50%	Expansive Soil
5.	Liquid Limit (w_L)	47.5%	-
	Plastic Limit (w_P)	17%	-
	Shrinkage Limit (w_S)	12%	-
	Plasticity index (I_p)	29.5%	I_p>17 High Plastic
	Soil Classification	CI	Clay of Intermediate Compressibility
6.	Optimum Moisture Content	22.16%	-
	Dry Density	1.654g/cc	-
7.	Unconfined compressive strength (q_u)	84.60 kN/m^2	-
	Cohesion (C_u)	42.3kN/m^2	-

Table.2 Standard Proctor's Compaction test results of soil+ Coal ash

Sl. No	%Coal ash	Optimum Moisture Content (%)	Maximum Dry Density(g/cc)
1	0	22.16	1.654
2	10	23.157	1.625
3	20	24.120	1.57
4	30	25.20	1.49
5	40	26.53	1.426
6	50	25.62	1.384
7	60	23.97	1.312

4.2 Unconfined Compression Strength Tests

Unconfined Compressive Strength tests was performed on the soil sample mixed with varying amount of coal ash such as 0%,10%,20%,30%,40%,50% and 60% of Fly ash + Bottom ash combinations. From this test the shear strength characteristics of the soil samples were studied by determining unconfined compression strength and undrained cohesion. Table 3 gives the UCC Strength test results of soil + Coal ash combinations.

Table.3 UCC strength test results of soil+ Coal ash (Fly ash + Bottom ash)

Sl. No	%Coal ash	Unconfined Compression Strength (kN/m²)	Undrained Cohesion (kN/m²)
1	0	84.60	42.30
2	10	145.86	72.93
3	20	188.45	94.22
4	30	241.33	120.66
5	40	290.748	145.374
6	50	257.21	128.605
7	60	176.43	88.215

4.3 California bearing ratio test

The CBR tests were conducted as per IS 2720(Part 16) -1987. CBR is the prime factor which determines the thickness of each pavement layer in the design of pavement .It is the ratio expressed in percentage of force per unit area required to penetrate a soil mass. The load values to cause 2.5mm and 5mm penetration are noted. These loads are expressed as standard load values. The standard load values are 1370kg and 2055 kg at 2.5mm and 5.00mm respectively. Generally, the CBR value at2.5mm penetration will be greater than that at 5mm penetration and in such a case, the former shall be taken as the CBR value for design purposes. The soaked CBR value is determined by subjecting the specimen in the mould for four day soaking. California Bearing Ratio test was performed on the soil sample mixed with varying amount of coal ash such as 10%, 20%, 30%, 40%, 50% and 60%.From this test the strength characteristics of the soil samples are studied by determining California Bearing Ratio value.

4.4 Determination of California Bearing Ratio Value

The California Bearing Ratio Value was determined in the laboratory by conducting California Bearing Ratio Test. The test was carried as per IS2720 (Part 16)-1987 in soil with coal ash and the California Bearing Ratio value are listed in the table 4 and table 5.

Table.4 California Bearing Ratio value of soil with coal ash for 2.5mm penetration

Sl.No	%Coal ash	Unsoaked CBR value (%)	Soaked CBR value (%)
1	0	6.697	3.348
2	10	7.366	4.018
3	20	8.036	5.022
4	30	9.284	6.157
5	40	10.153	7.362
6	50	9.348	6.418
8	60	8.457	5.784

Table.5 California Bearing Ratio value of soil with coal ash for 5.0mm penetration

Sl.No	%Coal ash	Unsoaked CBR value (%)	Soaked CBR value (%)
1	0	5.134	2.678
2	10	6.027	3.571
3	20	7.14	3.795
4	30	7.862	4.294
5	40	8.794	5.058
6	50	7.526	4.273
8	60	6.268	3.587

5. Results and Discussion

This elaborates the results obtained from the above tests on soil sample with Coal ash content is obtained based on the results of CBR tests and UCC tests.

5.1 properties of soil

The Various Properties of the sub grade soil namely natural moisture content, specific gravity, liquid limit, plastic limit, shrinkage limit and grain size distribution, optimum moisture content, maximum dry density, unconfined compressive strength and CBR obtained from section 4 are summarized in Table 6.

Table.6 Properties of soil

Sl.No	Properties	Results
1	Initial Moisture Content	7.20%
2	Specific Gravity	2.71
3	Percentage of sand	30.5%
	Percentage of silt	22.1%
	Percentage of clay	45.3%
4	Soil classification	CI
5	Optimum Moisture Content	22.16%
	Maximum Dry density	1.654 g/cc
7	Unconfined Compressive Strength	0.0846N/mm^2
	Cohesion	0.0423N/mm^2
9	CBR(Unsoaked condition, 2.5mm penetration)	6.697%
	CBR(Soaked condition, 2.5mm penetration)	3.348%
10	CBR(Unsoaked condition, 5mm penetration)	5.134%
	CBR(Soaked condition, 5mm penetration)	2.678%

5.2 Standard Proctors Compaction test

Standard Proctor's Compaction tests are conducted on soil samples under equal proportioning with 0%,10%,20%,30%,40%,50% and 60% of Fly ash + Bottom ash combinations were elaborated in section 5.The variation in maximum dry density and optimum moisture content with addition of Fly ash + Bottom ash combinations is shown in Fig.1 and 2.

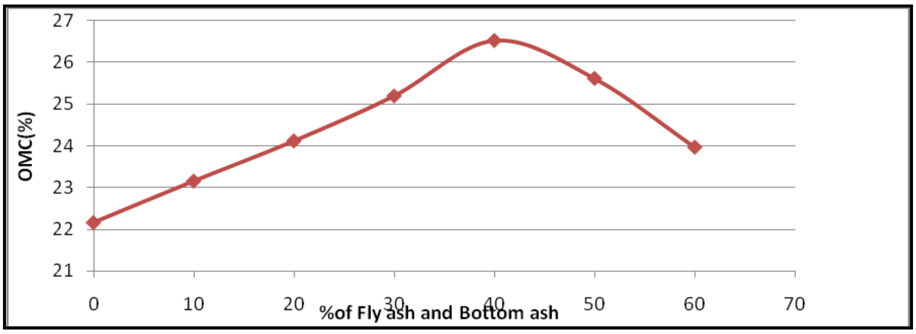

Figure.1 % of Fly ash+Bottom ash vs OMC (%)

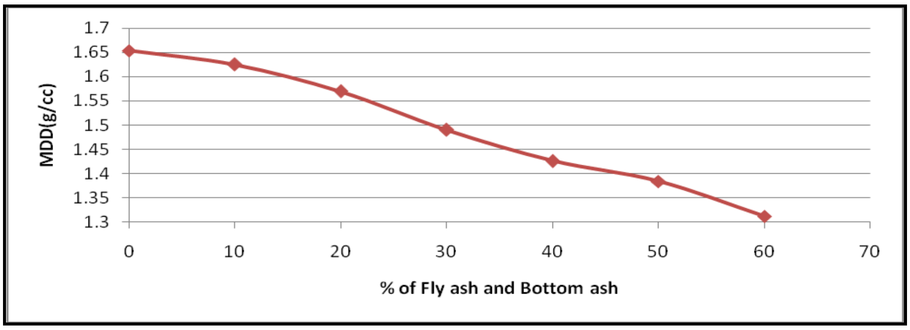

Figure.2 % of Fly ash + Bottom ash vs MDD (g/cc)

The variation in maximum dry density and optimum moisture content with addition of Coal ash is shown in Fig.1 and 2.

5.3 Atterberg's limit test

Consistency test was performed on the soil added with different percentage of Coal ash (Fly ash + Bottom ash) such as 0%, 20%, 30%, 40%, 50% and 60%.From this test the liquid limit of the treated samples were studied. The liquid limit test was conducted as per IS 2720(Part 5)-1985.The variation of liquid limit with addition of Coal ash is shown in Fig.3.

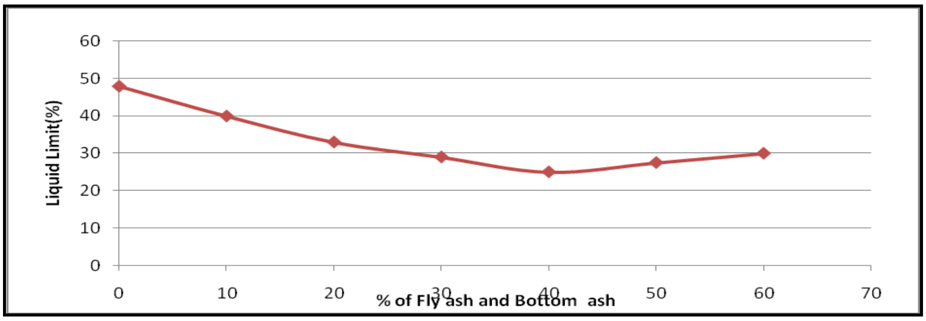

Figure.3 % of Fly ash + Bottom ash vs Liquid Limit (%)

5.4 Unconfined compressive strength test.

Unconfined compressive strength tests are conducted on soil samples with 0%,10%,20%,30%,40%,50% and 60% of Fly ash + Bottom ash combinations. The unconfined compressive strength and cohesion corresponding to various percentages of Fly ash + Bottom ash combinations, were elaborated in section 5.The variation in unconfined compressive strength and cohesion with addition of Coal ash is shown in Fig.4.

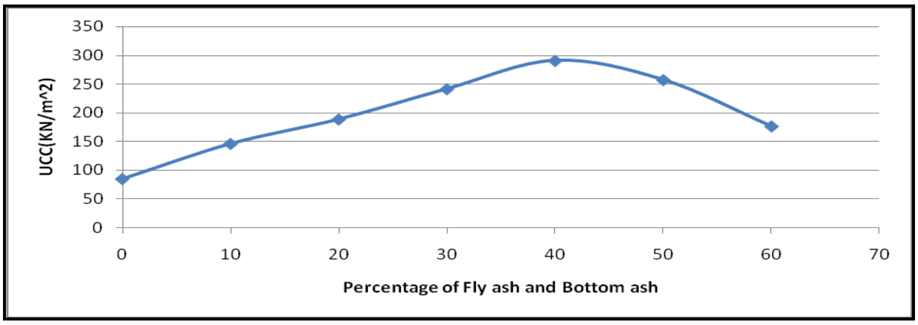

Figure.4 % of Fly ash + Bottom ash vs UCC (kN/m²)

5.5 California bearing ratio test

California bearing ratio tests are conducted on soil samples and on soil samples with 0%,10%,20%,30%,40%,50% and 60% of Fly ash + Bottom combinations. The tests were carried out on samples prepared under both light and heavy compaction and both unsoaked and soaked conditions. The CBR value corresponding to various percentages of Fly ash + Bottom ash combinations, were elaborated in Section 5.

The variation in the unsoaked and soaked CBR value with addition of Fly ash +Bottom ash combinations is shown in Fig 5.

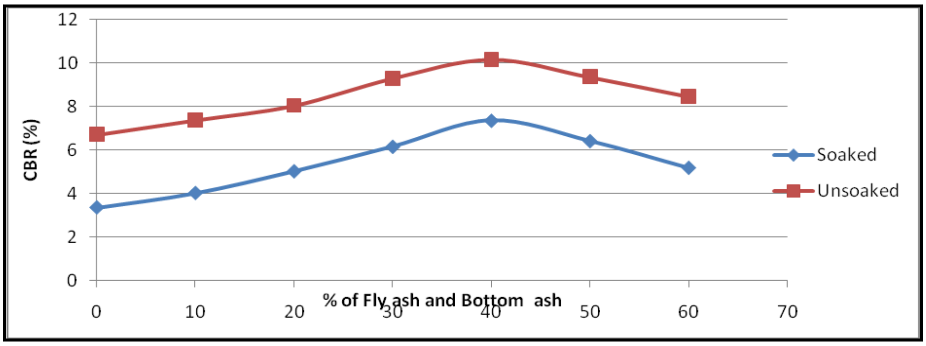

Figure.5 % of Fly ash + Bottom ash vs CBR (%)

6. Conclusion

The characteristics and strength of a highly expansive soil can be improved by Coal ash stabilization. The main aim of our research is to use Coal ash effectively to bring down the cost of construction of the roads and achieved the goal of research.

From the results, the following conclusions are warranted.

- Liquid Limit and Plasticity index are decreased with percentage Coal ash added.
- The California Bearing Ratio can be increased 1.34 times approximately to the initial strength of the soil.
- From the test data it is identified that Expansive soil Coal ash mixes attained high strengths at their optimum moisture and plastic limits. 10- 40% of Coal ash makes the Expansive Soil–Coal ash mixes strong and Non-swelling can be used as sub grade and in other geotechnical applications.

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