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EXPERIMENTAL STUDY ON THE EFFECT OF UTILIZATION OF INDUSTRIAL WASTE IN SUB-GRADE LAYER OF FLEXIBLE PAVEMENT

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ABSTRACT

The growing cost of traditional stabilizing agents and the need for the economical utilization of industrial and agricultural wastes has prompted an investigation into the stabilizing potential of coal ash (CA), groundnut shell ash (GSA) and bagasse ash (BA) in highly expansive soil. In this study an attempt has been made to utilize the industrial and agricultural wastes such as coal ash, groundnut shell ash and bagasse ash as a stabilizing agent. The effect of industrial and agricultural wastes under individual and combinations (equal proportion) of mix proportions on certain properties of soil such as Optimum Moisture Content (OMC), Maximum Dry Density (MDD), Unconfined Compressive (UCC) Strength and CBR has been studied. Index properties of natural soil showed that it belongs to CH in the IS classification system, soils under this group have poor engineering benefit. It has been observed that 30% of CA and 8% of GSA and BA for individual mix proportions and 12% CA + 12% GSA, 16% CA + 16% BA and 16% BA + 16% GSA for the combinations of mix proportions, are the optimum percentage that gives the maximum CBR value.

INTRODUCTION

Disposed coal ash is a result from the residue of coal refin- ery processes and has become an environmental important issue. Coal ash consists of bottom ash (5-15%) and fly ash (85-95%). In engineering practice, utilization of coal ash is limited and in small quantity, while the disposal of coal ash is quite high. In our country, there are about 130 thermal power plants, producing around 100 million tones of fly ash as waste material. Since the fly ash has pozzolanic prop- erty, it can be utilized as an alternative cementitious mate- rial in civil engineering applications. The disposal problem of fly ash can be avoided up to certain extent by using it for the construction of roads, airfields, and embankments and in fly ash brick industry etc. Sugarcane bagasse is a fibrous waste-product of the sugar refining industry, along with etha- nol vapour. This waste product causes serious environmen- tal pollution, which calls for urgent ways of handling the waste. Bagasse ash mainly contains aluminium ion and silica. Groundnut shell is an agricultural waste obtained from milling of groundnut. The ash

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from groundnut shell has been categorized under pozzolana. The utilization of this pozzolana as a replacement for traditional stabilizers will go a long way in actualizing the dreams of most developing countries of scouting for cheap and readily available con- struction materials. Groundnut shell ash has been used in concrete as a partial replacement material for cement with a measure of success achieved (Jaganatha Rao & Jai Bagwan 2001, Bhuvaneshwari et al. 2005, Ahmad rifa'i et al. 2009, Aigbodion et al. 2010, Kumar et al. 2010, Amu et al. 2011).

Problematic soils such as expansive soils are normally encountered in foundation engineering designs for highways, embankments, retaining walls, backfills, etc. Expansive soils are normally found in semi-arid regions of tropical and tem- perate climatic zones and are abundant, where the annual evaporation exceeds the precipitation and can be found any- where in the world. 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 colours, ranging from light grey to dark grey and black. The mineralogy of this soil is domi- nated by the presence of montmorillonite which is charac- terized 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 traditional stabi- lizer for expansive clays are bitumen, lime and cement. A 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 in- dustrial and agricultural wastes, etc. as stabilizing agents for the purpose of full or partial replacement of traditional sta- bilizers. Industrial and agricultural wastes are increasingly becoming a focus of researchers because of the enhanced pozzolanic capabilities of such waste when oxidized by burn-

Table 1: Mineral composition of coal ash.

Mineral Composition	Bott as (%) om h	Fly (%) ash
Silica (SiO_2)	33.2 5	50.40
Alumina (Al_2O_3)	21.4 1	16.57
Iron Oxide (Fe_2O_3)	30.3 7	7.9 5
Calcium Oxide (CaO)	6.44	6.0 7
Magnesium Oxide (MgO)	2.78	4.5 1
Potassium Oxide (K_2O)	1.10	1.1 7
Sodium Oxide (Na_2O)	1.32	1.3 1
Titanium Oxide (TiO_2)	0.80	0.6 2
Loss on Ignition (LOI)	0.76	9.7 5
Phosphorus (P_2O_5)	0.58	0.1 9
Sulphur (SO_3)	0.24	1.1 0

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Table 2: Mineral composition of groundnut shell ash.

Mineral Composition shell	Groundnut as (%) h
Silica (SiO_2)	41.36
Alumina (Al_2O_3)	6.73
Iron Oxide (Fe_2O_3)	3.16
Calcium Oxide (CaO)	8.91
Magnesium Oxide (MgO)	5.72
Potassium Oxide (K_2O) + Sodium Oxide (Na_2O)	17.38
Carbonite ions (CO_3)	7.02
Sulphur (SO_3)	5.4

Table 3: Mineral composition of groundnut shell ash.

Mineral Composition	Bagasse (%) ash
Silica (SiO_2)	77.34
Alumina (Al_2O_3)	9.55
Iron Oxide (Fe_2O_3)	3.61
Calcium Oxide (CaO)	2.15
Manganese Oxide (MnO)	0.13
Potassium Oxide (K_2O)	3.46
Sodium Oxide (Na_2O)	0.12
Titanium Oxide (TiO_2)	0.50
Loss on Ignition (LOI)	0.42
Phosphorus (P_2O_5)	1.07
Barium Oxide (BaO)	0.16

ing. Thus, this study is aimed at evaluating the possibility of utilizing industrial and agricultural wastes in the stabilization of black cotton soils (Krishna Swamy & Santhosha Rao 1995, Sinha et al. 1995, Sudip Basak et al. 2004, Praveen Kumar et al. 2005, Alhassan & Mustapha 2007, Alhassan 2008, Oriola et al. 2010).

MATERIALS AND METHODS

The effects of industrial and agricultural wastes such as coal ash, bagasse ash and groundnut shell ash in the subgrade of flexible pavement systems, were studied under both light and heavy energy of compaction. Soil sample collection: Bulk soil samples for the analysis were collected from NH 47 ongoing project of Chengapalli to Walayar, at 143 chainage lengths of Nilambur, Coimbatore, Tamilnadu State, India. The project site was located at 18 km from Coimbatore.

Material collection: Industrial and agricultural wastes such as coal ash, bagasse ash and groundnut shell ash are the materials collected for this study. Coal ash was collected from Neyveli Lignite Corporation (NLC) Ltd., Neyveli, Tamilnadu State. Bagasse ash was collected from Sakthi Sugars at Bhavani, Tamilnadu State and groundnut shell ash was col- lected from M/s Sivakumar Groundnut and Oil Mills in Pollachi, Tamilnadu State. The mineral composition of the three materials is given in Tables 1, 2 and 3.

Tests on materials: Laboratory tests were conducted in the geotechnical laboratory for the collected soil samples to clas- sify the soil, evaluate its physical and engineering proper- ties and to study the compaction characteristics. Proctor's Compaction tests,

UCC tests, and CBR (unsoaked and soaked) tests were conducted on samples with 0%, 10%, 20%, 30% of CA, 0%, 4%, 8%, 12% of BA, 0%, 4%, 8%,
12% of GSA contents and 0%, 4%, 8%, 12%, 16%, 20% of CA+BA, CA+GSA, BA+GSA contents. All the tests were conducted on samples prepared under both light and heavy energy of compaction. 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. Results obtained were compared and conclusions were made based on the results obtained.

Laboratory investigations: The laboratory investigation elaborates the various physical and engineering properties of subgrade soil, namely natural moisture content, specific gravity, liquid limit, plastic limit, shrinkage limit, grain size distribution, optimum moisture content, maximum dry den- sity, unconfined compressive strength and CBR, along with the mineral composition of coal ash, bagasse ash and ground- nut shell ash. All the tests were carried out as per IS codes. The various properties of the subgrade soil are summarized in Table 4. The mineral composition of coal ash, bagasse ash and groundnut shell ash is reported in Table 4.

Experimental Study

The experimental study involves Standard Proctor's Compaction test, Unconfined Compressive Strength test and California Bearing Ratio tests on soil samples under indi- vidual and combinations of mix proportions with varying percentage of coal ash, bagasse ash and groundnut shell ash content. All the tests were conducted with light and heavy energy of compaction.

Table 4: Properties of subgrade soil summary.

S.No.	Test conducted	Properties	Results
1	Determination of moisture content	Moisture Content	13.29%
2	Determination of specific gravity	Specific Gravity	2.63%
3	Grain Size Distribution	Percentage of sand	26.25%
		Percentage of silt	21.39%
		Percentage of clay	52.36%
4	Attreberg limit	Soil classification	CH
5	Compaction test(Light compaction)	Optimum Moisture Content	24.83%
		Maximum Dry density	1.522 g/cc
6	Heavy compaction	Optimum Moisture Content	15.71%
		Maximum Dry density	1.73 g/cc
7	Determination of Unconfined Compressive Strength (Light compaction)	Unconfined Compressive Strength	0.126N/mm^2
		Cohesive strength	0.063N/mm^2
8	Heavy compaction	Unconfined Compressive Strength	0.201N/mm^2
		Cohesive strength	0.101N/mm^2
9	Determination of California Bearing Ratio:		
	Light compaction and unsoaked condition	CBR	2.45%
	Light compaction and soaked condition	CBR	1.63%
10	Heavy compaction and unsoaked condition	CBR	5.88%
11	Heavy compaction and soaked condition	CBR	2.44%

California bearing ratio (CBR) tests: California bearing ratio test is conducted on soil samples prepared under both light and heavy compaction under both unsoaked and soaked conditions to determine the CBR value of soil with varying percentage of coal ash, bagasse ash and groundnut shell ash content. The test was conducted on soil samples with 10%, 20%, 30% of coal ash, 4%, 8%, 12% of bagasse ash, 4%, 8%, 12% of groundnut shell ash and 0%, 4%, 8%, 12%, 16%, 20% of CA+BA, CA+GSA, BA+GSA contents, and to determine the optimum coal ash, bagasse ash and ground- nut shell ash and CA+BA, CA+GSA, BA+GSA contents. The load vs

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penetration curves obtained from the tests are shown in Figs. 1, 2 and 3. The unsoaked CBR values of soil with coal ash, bagasse ash and groundnut shell ash are reported in Table 5, 6 and 7. The soaked CBR values of soil + CA + GSA, CA + BA and BA + GSA combinations under light compaction are given in Table 9.

The unsoaked CBR values of soil + CA + GSA, CA + BA and BA + GSA combinations under heavy compaction are reported in Table 10. The soaked CBR values of soil + CA + GSA, CA + BA and BA + GSA combinations under heavy compaction are depicted in Table 11.

RESULTS AND DISCUSSION

The results were obtained from the above tests on soil sam- ple with CA, BA, GSA and soil + CA + GSA, CA + BA and BA + GSA combinations. The optimum CA, BA, GSA con- tents and soil + CA + GSA, CA + BA and BA + GSA con-

Table 5: Unsoaked CBR test results of soil + coal ash.

% of C.A	0%	10 %	20 %	30%
CBR %	2.4 5	6.5 5	7.5 1	8.36

Table 6: Unsoaked CBR test results of soil + bagasse ash.

% of B.A	0%	4%	8%	12%
CBR %	2.4 5	6.9 3	7.1 4	6.80

Table 7: Unsoaked CBR test results of soil + groundnut shell ash.

% of GSA	0%	4%	8%	12%
CBR %	2.45	6.53	7.34	6.93

Table 8: Unsoaked CBR test results of soil + CA + GSA, CA + BA and BA + GSA (light compaction).

Percentage	0%	4%	8%	12%	16 %	20 %
CBR %, C.A+GSA	2.4 5	6.7 9	7.8 8	8.97	8.6 9	9.24
CA+BA	2.4 5	6.1 1	6.9 3	7.34	7.4 8	7.07
BA+GSA	2.4 5	6.2 5	7.0 7	8.02	8.6 9	8.56 3

Table 9: Soaked CBR test results of soil + CA + GSA, CA + BA and BA + GSA (light compaction).

Percentage.	0%	4%	8%	12%	16%	20%
Percentage	0%	4%	8%	12%	16%	20%
CBR %, CA+GSA	1.63	4.757	6.11	7.88	7.33	7.747
CA+BA	1.63	3.81	5.16	6.524	6.79	6.524
BA+GSA	1.63	4.35	5.7	6.524	7.88	7.475

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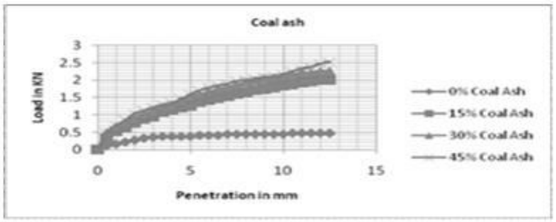

Fig. 1: Load vs penetration curves (Soil + Coal ash).

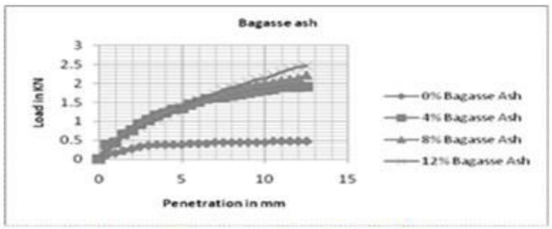

Fig. 2: Load vs penetration curves (Soil + Bagasse ash).

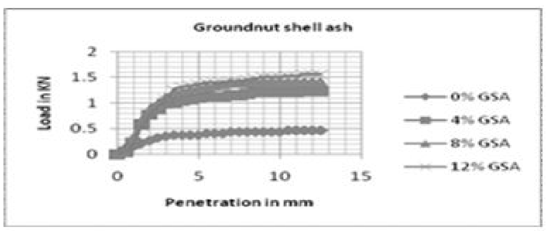

Fig. 3: Load vs penetration curves (Soil + Groundnut shell ash).

tents were obtained based on the results of CBR tests and UCC tests.

California Bearing Ratio (CBR) Test

California bearing ratio tests are conducted on soil samples and on soil samples with 0%, 10%, 20%, 30% of CA; 0%, 4%, 8%, 12% of BA; 0%, 4%, 8%, 12% of GSA and 0%, 4%, 8%, 12%, 16%, 20% of CA + BA, CA + GSA, BA + GSA contents. The tests were carried out on samples pre-pared under both light and heavy compaction and both unsoaked and soaked conditions. The CBR values corre- sponding to various percentages of CA, BA, GSA and CA + GSA, CA + BA and BA + GSA combinations are shown in Figs. 4, 5 and 6. From Fig. 4, it is seen that the unsoaked CBR of untreated soil sample prepared with light compaction is 2.45% and the CBR of sample treated with 10%, 20% and 30% coal ash

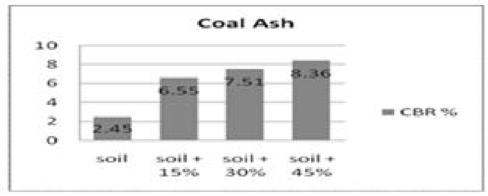

Fig. 4: CBR (Soil + Coal ash).

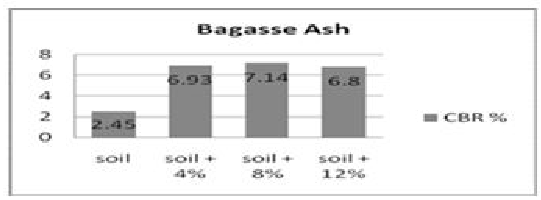

Fig. 5: CBR (Soil + Bagasse ash).

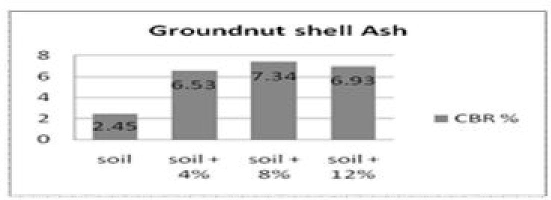

Fig. 6: CBR (Soil + Groundnut shell ash).

is 6.55, 7.51 and 8.36 respectively. This shows that the addi- tion of coal ash under light compaction and unsoaked con- dition has significant improvement in CBR value. From Fig. 5, it is observed that the unsoaked CBR of un- treated soil sample prepared with light compaction is 2.45% and the CBR of sample treated with 4%, 8% and 12% bagasse ash is 6.93, 7.14 and 6.8 respectively. This shows that the ad- dition of bagasse ash under light compaction and unsoaked condition has significant improvement in CBR

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value.From Fig. 6, it is seen that the unsoaked CBR of un- treated soil sample prepared with light compaction is 2.45% and the CBR of sample treated with 4%, 8% and 12% groundnut shell ash is 6.535, 7.34 and 6.93 respectively. This indicates that the addition of ground nut shell ash un- der light compaction and unsoaked condition has signifi- cant improvement in CBR value.

Table 10: Un Soaked CBR test results of soil+ C.A + GSA, C.A + B.A and B.A + GSA (Heavy compaction).

Percentage	0%	4%	8%	12%	16%	20%
CBR %,C.A+GSA	5.88	8.43	9.51	10.87	10.60	11.42
C.A+B.A	5.88	8.02	9.24	10.33	11.96	11.00

Table 11: Soaked CBR test results of soil+ C.A + GSA, C.A +B.A and B.A + GSA (Heavy compaction).

Percentage	0%	4%	8%	12%	16%	20%
CBR %,C.A+GSA	2.24	6.755	7.88	8.97	8.83	9.10
C.A+B.A	2.24	6.12	7.48	8.70	9.79	9.65
B.A+GSA	2.24	6.524	7.88	8.69	9.24	9.10

CONCLUSIONS

Based on the laboratory tests and experimental studies car- ried out in the above study, the following conclusions were drawn.

a. Subgrade soil used in this study was classified as clay of high plasticity.

b. The CBR value of soil collected is very less and it pro- vides an opportunity to improve the soil by using indus- trial and agricultural wastes such as coal ash, bagasse ash and groundnut shell ash as a stabilizing agent.

c. The CBR values increased upon addition of 8% of ba- gasse ash and 8% of groundnut shell ash and decreased with further increase in bagasse ash and groundnut shell ash content.

d. From the CBR values and UCC values, the optimum coal ash content is 30%, bagasse ash content is 8% and ground- nut shell ash content is 8%.

e. The percentage increase in the CBR value is 241% by use of coal ash under light compaction and unsoaked condition.

f. The percentage increase in the CBR value is 191% by using the bagasse ash under light compaction and unsoaked condition.

g. The percentage increase in the CBR value is 200% by using of groundnut shell ash under light compaction and unsoaked condition.

h. The soaked CBR value of untreated soil is 1.63% and 2.24% under both light and heavy compaction and hence it requires to be stabilized.

i. The CBR values increased upon addition of 12% coal ash + 12% groundnut shell ash, 16% coal ash + 16% bagasse ash and 16% bagasse ash + 16% groundnut shell ash and decreased with further increase in coal ash, ba- gasse ash and groundnut shell ash content.

j. From the CBR values and UCC values the optimum per- centage of combinations are 12% coal ash + 12% ground- nut shell ash, 16% coal ash + 16% bagasse ash and 16% bagasse ash + 16% groundnut shell ash.

k. The percentage increase in the unconfined compressive strength value is 104.76%, 97.62% and 107.94% for re- spective combinations under light compaction.

l. The percentage increase in the soaked CBR value is 383.44%, 316.933%, 383.62% for respective combina- tions under light compaction condition.

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