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Original Research Paper

Experimental Study of Bagasse Ash Utilisation for Road Application on Expansive Soil

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ABSTRACT

Expansive soils show extensive volume and their strength changes at varying moisture content due to their chemical composition. This causes significant structural damage to foundations, including pavements. One way of overcoming these problems in soils is to stabilize them with admixtures. Owing to this fact, continuous researches have been carried out and still being carried out by individuals, firms and institutions on ways to improve the engineering properties of soils. The need to bring down the cost of soil stabilizers and the environmental damage has led to intense global research towards economic utilization of wastes for engineering purposes. Bagasse ash is a waste-product of the sugar refining industry. This study was carried out to determine the effect of bagasse ash utilization for road application on clay. The laboratory investigations are carried out to examine the index and engineering properties of the soil sample. The soil falls under CI category of Indian standard soil classification system. The experiments have been carried out to study the changes in the properties of soil such as plasticity characteristics, free swell index, pH, calcium carbonate content, total dissolved solids and cation exchange capacity using bagasse ash in varying percentages of 2%, 4%, 6%, 8% and 10%. The study shows promising results with effective utilization of bagasse ash in the improvement of soil strength.

INTRODUCTION

Infrastructure projects such as highways, railways, water reservoirs, reclamation etc. require earth material in very large quantities. In urban areas, borrow earth is not easily available which has to be hauled from a long distance. Quite often, large areas are covered with highly plastic and expansive soil, which is not suitable to be used as earth material. Extensive laboratory and field trials have been carried out by various researchers and have shown promising results for application of such expansive soil after stabilization (Bhuvaneshwari et al. 2005).

Expansive clay soils are those that change significantly in volume with changes in water content. The problem with expansive soils has been recorded all over the world. In monsoon they imbibe water and swell and in summer they shrink on evaporation of water from them. Because of this alternative swelling and shrinkage, lightly loaded civil engineering structures like residential buildings, pavements and canal linings are severely damaged. It is, therefore, necessary to mitigate the problems posed by expansive soils and prevent cracking of structures. This creates engineering problems and affects the service of structures and riding qualities on pavements. The annual cost of damage due to the expansive soil has been increased. Also the need for adequate provisions of transportation facilities are enormously increasing with increase in population along with the maintenance of existing ones. Highway engineers are faced with the problems of providing very suitable materials for the highway construction. Owning to this fact, continuous researches have been carried out and still being carried out by individual, firms and institutions on ways to improve the engineering properties of the soils. The most available soils do not have adequate engineering properties to really bear the expected wheel load. So improvisations have to be made to make these soils better. This leads to the concept called soil stabilization, which is, any treatment (including technical, compaction) applied to a soil to improve its strength and reduce its vulnerability to water. If the treated soil is able to withstand the stresses imposed on it by traffic under all weather conditions without excessive deformation, then it is generally regarded as stable (Osinubi et al 2007, Ahmad rifa'I. et al. 2009, Oriola et al. 2010, Bhuvaneshwari et al. 2005, Bilba et al. 2003, Ken C. Onyelowe 2012, Medjo Eko & Riskowiski 2004, Moses & Osinubi 2013).

The need to bring down the cost of waste disposal and the growing cost of soil stabilizers, has lead to intense global research towards economic utilization of wastes for engineering purposes. The safe disposal of industrial and agricultural waste products demands urgent and cost effective solutions because of the debilitating effect of these materials on the environment and to the health hazards that these wastes constitute (Oriola et al. 2010, Kolawole et al. 2012, Mohammed Abdullahi 2007, Mohammedbhai & Baguant 1985, Osinubi & Eberemu 2006, Moses & Osinubi 2013).

Bagasse is the matted cellulose fibre residue from sugarcane that has been processed in a sugar mill. Sugar cane bagasse is a fibrous waste product of the sugar refining industry, along with ethanol vapour. This waste-product is already causing serious environmental pollution, which calls for urgent ways of handling the waste. To stabilize expansive soil, the waste product bagasse ash is collected from the boiler/furnace bed of sugar cane located at Sakthi sugars, Erode. This study was carried out to determine the effect of bagasse ash utilization for road application on clay (Oriola et al 2010, Moses and Osinubi 2013).

The laboratory investigations are carried out to examine the index and engineering properties of a soil sample. The soil sample for the analysis is collected from Cheran Mannagar, Coimbatore, Tamilnadu State, India and the location lies along 11.057°N latitude and 77.019°E longitude. The soil falls under the CI category of Indian standard soil classification system. The experiments were carried out to study the changes in properties of soil such as plasticity characteristics, free swell index, pH, calcium carbonate content, total dissolved solids and cation exchange capacity using bagasse ash in varying percentages of 2%, 4%, 6%, 8% and 10%. This study shows promising results with effective utilization of bagasse ash in improvement of soil strength.

MATERIALS AND METHODS

Soil sample for the analysis was collected from Coimbatore-Cheran Maanagar, Tamilnadu State, India and Bagasse ash was collected from Sakthi Sugars, Erode, Taminadu State, India. Laboratory tests were conducted on the soil sample to classify the soil and to determine its index and engineering properties. The collected soil sample was mixed with various percentages of bagasse ash such as 2%, 4%, 6%, 8%, 10% in addition to the soil. Methodology is graphically represented in Fig. 1.

Laboratory Investigations

This elaborates the determination of various physical and engineering properties of the 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 California bearing ratio of the soil sample. The mineralogical content of bagasse ash was studied. The laboratory investigations were carried out as per IS codes. The properties of soil sample are summarized in Table 1.

Mineral content of soil sample and bagasse ash: The mineral content of soil sample was determined using X-ray diffraction (XRD) analysis. The XRD analysis of soil sample was carried out in Avinashilingam University, Coimbatore. The mineral composition of bagasse ash was obtained from Sakthi Sugars, Erode. The mineral content is listed in Table 2.

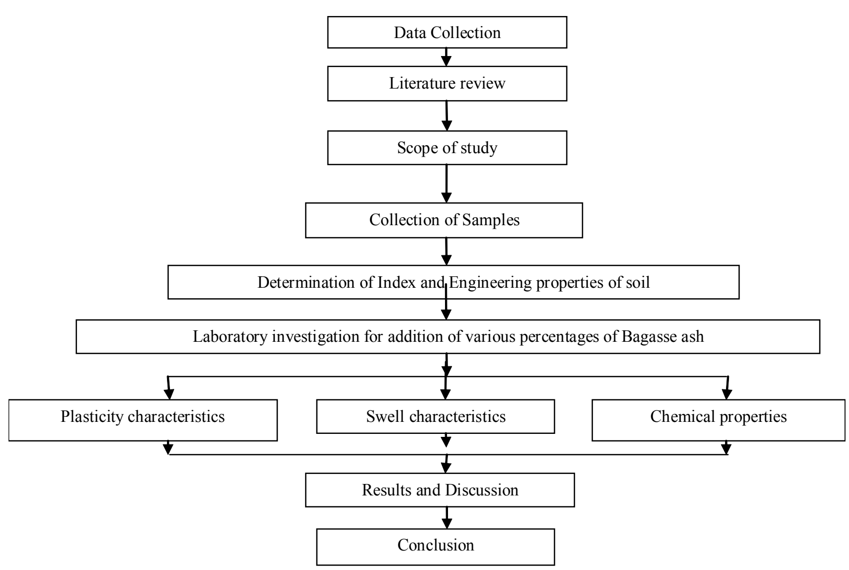

Fig. 1: Methodology for soil sample analysis.

Table 1: Properties of soil sample.

S.No.	Properties		Result
1	Initial Moisture Content		8.3%
2	Specific Gravity		2.71
3	Sieve Analysis		
		% of Gravel	2.1%
		% of sand	30.5%
		% of Silt	22.1%
		% of Clay	45.3%
4	Free Swell Index		50%
5	Liquid Limit (W_L)		47%
	Plastic Limit (W_P)		17%
	Shrinkage Limit (W_S)		12%
	Plasticity Index (I_P)		30%
6	Soil Classification		CI
7	Optimum Moisture Content		15%
	Maximum Dry Density		1.658 g/cc
8	Unconfined Compressive Strength (q_u)		84.12 kN/m^2
	Cohesion (C_u)		42.06 kN/m^2
9	CBR unsoaked, CBR soaked		12.88%,2.68 %

Table 2: Mineral content of soil and bagasse ash.

S.No.	Sample	Minerals
1	Bagasse ash	Silica, alumina, iron oxide, potassium oxide, calcium oxide, phosphorons, magnesium oxide Sodium oxide, Titanium oxide, Barium oxide
2	Soil sample	Quartz, kaolinite, illite, chlorite, felds

Table 3: Liquid limit, plastic limit and plasticity index of soil.

S. No.	% Ba	Liquid Limit (W_l) (%)	Plastic Limit ($Wp_)$ (%)	Plasticity Index (I_p) (%)
1	0	47	17	30
2	2	45	18	27
3	4	43	19	24
4	6	39	20	19
5	8	42	19.5	22.5
6	10	44	19	25

Table 4: Free Swell Index test values of soil.

S. No.	% BA	Free Swell (%)
1	0	50
2	2	40
3	4	35
4	6	30
5	8	43
6	10	45

Experimental Study

The experimental study involves the analysis of soil added with varying percentages of bagasse ash such as 2%, 4%, 6%, 8% and 10%. Here the treated samples are tested to determine its index properties and chemical properties like total soluble solids, pH, cation exchange capacity, calcium carbonate content and soluble sulphates.

Atterberg's limit test: Consistency test was performed on the soil added with different percentage of bagasse ash such as 2%, 4%, 6%, 8% and 10%. From this test the plasticity characteristics of the treated samples were studied.

Determination of liquid limit, plasticity limit and plasticity index: The consistency test was conducted as per IS 2720 (Part 5)-1985 and the readings are tabulated in Table 3.

Free swell index test: The free swell index test was performed on the soil added with different percentage of bagasse ash such as 2%, 4%, 6%, 8% and 10%. The test was conducted as per IS: 2720 (Part 40)-1977 and the readings are tabulated in Table 4.

Tests to determine chemical properties: The determination of chemical properties is an important phenomenon since this greatly influences the engineering properties of the soil. The chemical tests that are carried on samples are total soluble solids, pH, cation exchange capacity, calcium carbonate content and soluble sulphates. Since these tests greatly influence the engineering properties of soil, the test procedures are followed as per IS: 2720.

***Total soluble solids*:** Total soluble solids indicate the amount of the presence of soluble salts and other soluble materials in the soil. This test is done in accordance with IS: 2720 (Part 21)-1977 (gravimetric analysis) and also determined by using TDS meter. Results obtained from both the tests are tabulated in Table 5.

***Calcium carbonate ($CaCO_3$) content*:** The $CaCO_3$ content can be obtained from volumetric analysis as per IS: 2720 (Part 23)-1976. A 5g of soil is taken and 100 mL of 1N hydrochloric acid is added and stirred for an hour. Now the supernatant solution is titrated against sodium hydroxide with bromothymol blue indicator. The amount of calcium carbonate present in the samples is tabulated in Table 6.

***Determination of pH*:** The soil pH is a measure of acidity or basicity in soils. The pH of the samples was determined using the electrometric method specified by IS: 2720 part 26, which involves mixing the solids with pure water, periodically shaking samples, and then after 1 hour testing the supernatant solution with a pH meter. The results are given in Table 7.

***Cation exchange capacity (CEC)*:** The cation exchange capacity (CEC) of a soil is a measure of the quantity of negatively charged sites on soil surfaces that can retain positively charged ions (cations) such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+), by electrostatic forces.

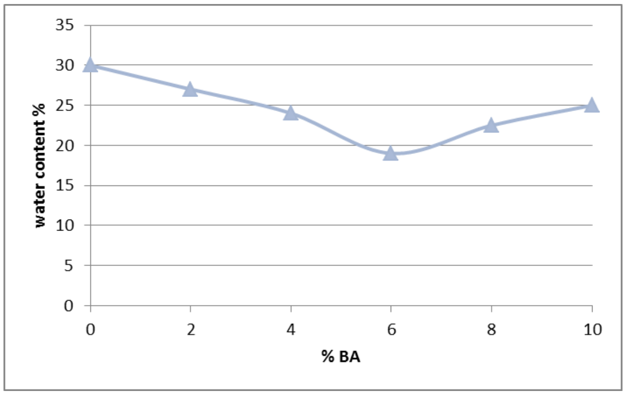

Fig. 2: Variation of plasticity index.

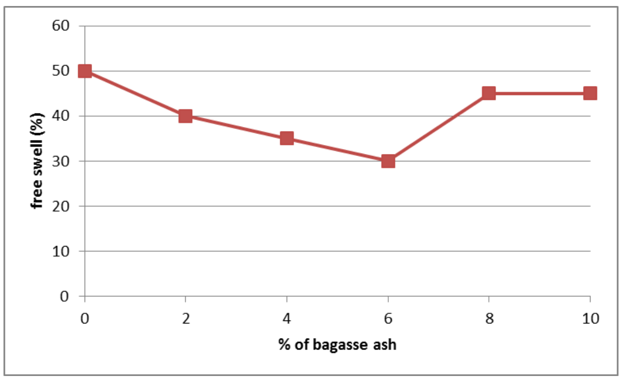

Fig. 3: Effect on free swell index.

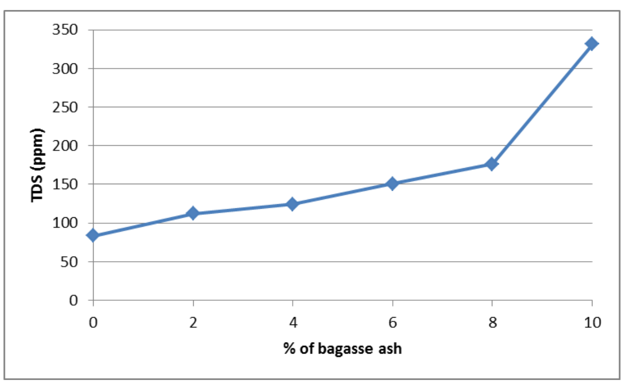

Fig. 4: Effect on total soluble solids.

The cation exchange capacity (CEC) of a soil is determined as per IS: 2720 (Part 24)-1974 and the readings are presented in Table 8.

***Soluble sulphate determination*:** The soluble sulphate content can be determined as per IS: 2720 (Part 27)-1977. This standard lays down the procedure for determining the total soluble sulphate of soil by three methods, namely, precipitation method (standard method), volumetric method, and colorimetric method. The last two methods being subsidiary methods; precipitation method is used in this analysis.

Table 5: Total soluble solids of soil.

S.No.	% BA	Solubles Solids (ppm) (by TDS Meter)	Soluble Solids (ppm)(IS Method)
1	0	83.5	82
2	2	112.3	114
3	4	124.3	123
4	6	151	152
5	8	176.2	175
6	10	331	329

Table 6: Calcium carbonate content of soil.

S.No.	% BA	Calcium carbonate (% by weight)
1	0	20
2	2	17.5
3	4	20
4	6	22.5
5	8	21
6	10	22

Table 7: pH of soil.

S.No.	% BA	pH
1	0	8.89
2	2	8.46
3	4	8.27
4	6	8.18
5	8	8.11
6	10	8.21

Table 8: Cation exchange capacity of soil.

S.No.	% BA	CEC (meq/100g)
1	0	87.6
2	2	64.5
3	4	59
4	6	31.3
5	8	33.6
6	10	34.1

It was observed that the sulphate present in the soil is 0.013% by mass. This shows only a trace of sulphate is present in the sample and there is no sulphate content in bagasse ash. Hence, there will be no significant change in the total soluble sulphate content of soil during the addition of bagasse ash. Hence, the soluble sulphate content in the soil and bagasse ash mixture is taken as nil.

RESULTS AND DISCUSSION

This elaborates the results obtained from various tests like consistency test, free swell index test, determination of to-

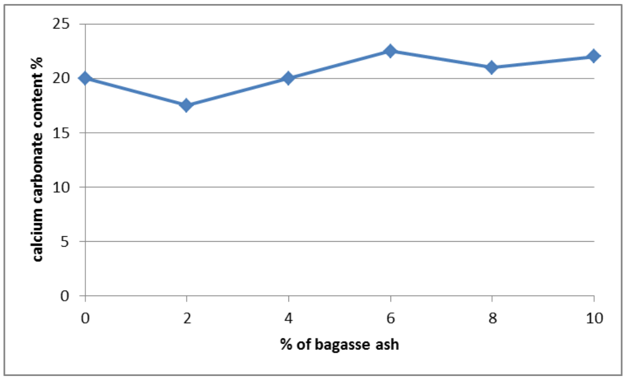

Fig. 5: Effect on $CaCO_3$.

Fig. 6: Effect on pH.

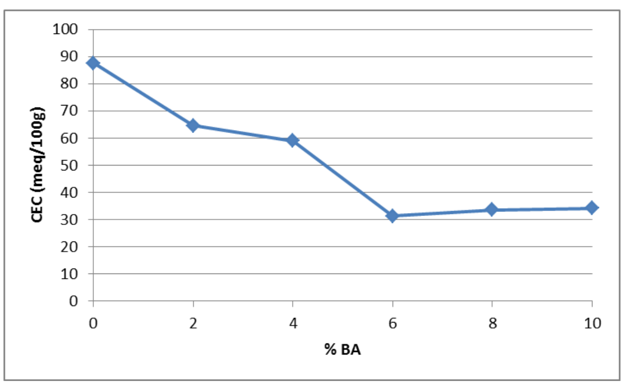

Fig. 7: Effect on cation exchange capacity.

tal soluble solids, pH, cation exchange capacity, calcium carbonate content and soluble sulphates.

Consistency test: Consistency test was performed on the soil added with different percentage of bagasse ash such as 2%, 4%, 6%, 8% and 10%. From this test the plasticity characteristics of the treated samples were studied. This test was conducted as per IS: 2720 (Part 5)-1985. The result of this test is depicted in Table 9.

Table 9: Liquid limit, plastic limit and plasticity index of soil.

S. No.	% Ba	Liquid Limit (W_l) (%)	Plastic Limit (W_p) (%)	Plasticity Index (I_p) (%)
1	0	47	17	30
2	2	45	18	27
3	4	43	19	24
4	6	39	20	19
5	8	42	19.5	22.5
6	10	44	19	25

It is observed from Fig. 2 that the plasticity index got reduced with the addition of bagasse ash and thus contributing to the improvement of soil properties.

Effect on free swell: The effect of swelling is observed in soil with varying percentage of addition of bagasse ash. As the percentage of bagasse ash addition increases, the free swell index got reduced and this effect on free swell index is shown in Fig. 3.

Effect on total soluble solids: Total soluble solids is the amount of dissolved solids in the sample. This increases with addition of bagasse ash. The increased soluble solid content with addition of bagasse ash, indicates the amount of bagasse ash available for binding actions. This gives a better result for the stabilization. The effect of addition of bagasse ash on total soluble solids is shown in Fig. 4.

Effect on calcium carbonate ($CaCO_3$) content: Calcium carbonate is a binding material which is also used as an additive in the chemical stabilization. The calcium carbonate content got increased with increase in bagasse ash content in soil. This content may vary with respect to time since binding process is a long time chemical reaction. The increase in calcium carbonate gives good results in the binding process. The effect of addition of bagasse ash on $CaCO_3$ is shown in Fig. 5.

Effect on pH: The pH of soil got decreased with increase in addition of various percentages of bagasse ash. The pH of the soil is slightly alkaline and this alkalinity reduces with the addition of varying percent of bagasse ash. The effect of addition of bagasse ash on pH is shown in Fig. 6.

Effect on cation exchange capacity: Cation exchange capacity indicates the amount of exchangeable ions adsorbed on the clay surface. Cation exchange capacity gives an indication of the affinity of soil for water and its capacity for swelling. Higher the cation exchange capacity, lower will be the strength. The effect of addition of bagasse ash on cation exchange capacity is shown in Fig. 7.

CONCLUSIONS

The following conclusions were obtained from the experimental study carried out.

1. With the increase in percentage of bagasse ash in soil, the plasticity index of the soil has decreased from 30% to 19%.
2. With the increase in percentage of bagasse ash in soil, its swelling has reduced from 50% to 30%.
3. It has been observed that the total soluble solids increase with the addition of bagasse ash.
4. It has been observed that the pH of the soil is 8.89 and this alkalinity reduces to 8.11 with the addition of bagasse ash.
5. With the addition of bagasse ash to the soil, the $CaCO_3$ content has increased.
6. Addition of bagasse ash to soil decreases the cation exchange capacity from 87.6 meq/100g to 31.3 meq/100g.

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