A Study on Strength Characteristics of Baggasse Ash and Phospho Gypsum Treated Marine Clay

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Abstract

Civilization is always developed around the coastal regions; these are covered with thick soft marine clay deposits. This clay has less strength and possesses high deformation, low permeability and limited bearing capacity. Due to the poor engineering characteristics of these clays, they pose several foundation problems to various coastal structures. As this Marine clay is widely occupied in costal corridor, it is inevitable to constructing pavements and foundations on them due to the population density. Therefore, the present experimental work aims to investigate the efficacy of Bagasse Ash and Phospho Gypsum in stabilizing the marine clay thereby improving its strength characteristics. Total cost of construction is reduced and also providing solution for environmental problem. From the experimental results it was observed that 20 % Bagasse Ash and 6% Phospho Gypsum combination with marine clay had effectively improved the CBR and UCS values.

Keywords: *Marine Clay, Bagasse Ash, Phospho Gypsum, Compaction, CBR, UCS.*

I. INTRODUCTION

Soil stabilization is a technique to improve the soil parameters such as shear strength, compressibility, density, hydraulic conductivity etc. Soil stabilization can be explained as the alteration of the soil properties by chemical or physical means in order to enhance the engineering quality of the soil. The soil found in the ocean bed is classified as marine soil. It can even be located onshore as well. The properties of saturated marine soil differ significantly from moist soil and dry soil. Marine clay is microcrystalline in nature and clay minerals like chlorite, kaolinite and illite and non-clay minerals like quartz and feldspar are present in the soil. Marine soils in particular can present great problems in pavement design due to uncertainty associated with their performance. They are often unstable beneath a pavement and they are the most susceptible to problems from changes in moisture content. The marine clays are found in the states of West Bengal, Orissa, Andhra Pradesh, Tamilnadu, Kerala, Karnataka, Maharashtra and some parts of Gujarat. [1] were used varying percentage and at varying curing periods to stabilize the soil by conducting geotechnical laboratory tests like Unconfined Compression Test (UCS), California Bearing Test (CBR) and Free Swelling Index Test (FSI) were carried by varying the percentage of sugarcane straw ash(5%, 10% and 15%) at varying curing periods (3, 5 and 7 days) and from the results, 10 % increase in the percentage of sugarcane straw ash increases the UCS and CBR value with increasing curing periods and with increase in the curing period, the UCS value increases. The increase of the UCS value is more significant for 10 % addition of SSA. The CBR value also increases with the increase in the curing period. The maximum CBR value is obtained for 10 % addition of SSA and decreases with further increase in the percentage of SSA. The swelling property reduces with the increase in the percentage of SSA and with increasing curing period. The swelling index found to be zero for 10% addition of SSA. The 10 % addition of SSA reduces the thickness of the pavement by 50 % thereby reducing the cost of construction. The optimum percentage of sugarcane straw ash (SSA) to be used as soil stabilizer is found to be 10 % having a curing period of 7 days. [2] Were study the effects of bagasse ash and lime on expansive soil and from various test results, there is a variation in the values of properties of soil due to the addition of Bagasse Ash and Lime. Soil is OH and it is converted into CH due tomixing of Bagasse Ash, 50% decrease in free swell value of B.C. soil and Maximum dry density increases with reduction in optimum moisture content. Variation observed in unconfined compression strength and values of cohesion and angle of internal friction. [3] Study to investigate feasibility of SCBA (Sugarcane Bagasse Ash) to stabilize the soil. Sugar factories produce waste after extraction of sugarcane in machines that waste when brunt, the resultant ash is known as Bagasse ash. Soil is treated with partial replacement of bagasse ash (4%, 8%, 12%, 16%, 20%, 24% and 28%) which affects the MDD and OMC up to an optimum percentage. The use of Sugarcane Bagasse Ash improves some properties of the clayey soil and can be used as replacement in clayey soil up to certain limits. It may be used in construction of rural roads etc. In the mean time the problem of disposal and handling may be solved. [4] Worked on bagasse ash as stabilizing material for expansive soils by conducting various experiments on black cotton soil with partial replacement by Bagasse Ash at 3%, 6%, 9% and 12% respectively. It was seen that due to addition of bagasse ash, CBR and Compressive strength increases almost by 40%, but density showed only significant change. The blend suggested 6% bagasse ash, without any addition of cementing or chemical material would be an economic approach. Further more if any cementing material is added in suggested blend, then there will be definitely more improvement in properties of expansive soils. [5] conducted series of Consolidated Drained triaxial tests at confining pressures of 50 kPa, 100 kPa and 150 kPa and from the results marine clay unconsolidated Undrained triaxial tests, cohesion value of untreated marine clay was 32.5 kN/m^{2}and maximum value of cohesion was obtained 47 kN/m^2, Consolidated Drained triaxial tests, cohesion value of untreated marine clay was found to be 11.25 kN/m^2 and maximum value of cohesion was obtained as 23.75 kN/m^2(percentage increase 111%) on addition of 5% Class F fly ash. Consolidated Drained triaxial tests were done on marine clay with optimum percentages of additives after 7 and 14 days of curing. Considerable strength increment was observed for treated soil samples after the curing period. [6] has studied the effect of Rice Husk ash and Lime on strength properties of marine clay and observed that, liquid limit of the marine clay has been decreased by 16.21% and further decreased by 29.86%, plastic limit improved by 7.40% and further improved by 16.29%;plasticity index has been decreased by 29.78% and further decreased by 56.38% ; OMC decreased by 18.52% and further decreased by 42.63%; MDD has been improved by 17.00% and further improved by 12.70% ;CBR increased by 282.0% and has been further improved by 449.14% ,DFS value of the marine clay has been decreased by 72.80% on addition of 25% Rice Husk Ash and it has been further decreased by 77.28% when 9% lime is added. The soaked CBR of the soil on stabilizing is found to be 9.632 and is satisfying standard specifications and finally concluded from the above results that the stabilized marine clay is suitable to use as subgrade material for the pavement construction and also for various foundations of buildings. [7] observed that the liquid limit, plastic limit and the plasticity index were significantly high and the OMC was below the plastic limit from the chemical analysis, the marine clay was found to possess significant proportion of carbonate content, organic matter content, cation exchange capacity and marginally alkaline. From the experimental results, U.U Triaxial test of a remoulded marine clayey soil sample, the value of Cohesion and Angle of internal friction were estimated as 0.12kN/m^2 and 3.50 respectively. From the vane shear tests it was also observed that with the increase in moisture content , the unit cohesion of the soil sharply dropped down to a value as low as 6 kPa. The load carrying capacity of the Marine Clay is high at its OMC to compare with FSC. It is observed from the test results that the time required for 90% consolidation is 311.6 days and from the test results that the marine clay is fall under the category of moderately swelling soil and the Swell Pressure is 160 kN/m^2. [8] Studied the geotechnical properties of lateritic soil using sugar cane straw ash as stabilizer. They found that there is an increase in the value of OMC, CBR and UCS on addition of 8 % sugar cane straw ash. They further concluded that sugar cane straw ash can be used as an effective soil stabilizer. In this investigation, different laboratory experiments like compaction, soaked and soaked CBR and unconfined compressive strength tests were conducted by varying percentages of Bagasse Ash i.e. 0%, 10%, 20% 30% and 40%, and Phospho Gypsum with 0 %,3 %, 6 % and 9% blended with marine clay with a view to determine optimum percentages. From the test results, it is found that there is an improvement in geotechnical properties and the optimum percentages of Bagasse Ash and Phospho Gypsum are 20% and 6 % respectively.

II. MATERIALS USED AND PROPERTIES

The details of the various materials used in the laboratory experimentation are reported in the following sections.

A. Marine clay

The marine clay used in this study and was typical soft clay. The marine clay was collected at a depth of 0.30m to 1.00m from ground level from Kakinada, Andhra Pradesh State, India. The properties of soil are presented in the Table. I. All the tests carried on the soil are as per IS specifications.

table I: PROPERTIES OF MARINE CLAY

S.No.	Property	Value
1	Specific Gravity	2.61
2	Differential Free Swell Index (%)	39
3	Atterberg's Limits	
	i) Liquid limit (%)	72.8
	ii) Plastic limit (%)	27.2
	iii) Plasticity index (%)	45.6
5	Grain Size Distribution	
	i) Sand Size Particles (%)	8
	ii) Silt & Clay Size Particles (%)	92
6	IS soil classification	CH

7	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.36
	ii) Optimum Moisture Content (%)	29.5
8	CBR - Soaked (%)	1.4
9	Shear Parameters	
	i) Cohesion, Cu (kPa)	36
	ii) Angle of Internal Friction, (Øu)	0^0

B. Baggasse Ash

Sugarcane bagasse (SCB) which is a voluminous by-product in the sugar mills when juice is extracted from the cane. It is, however, generally used as a fuel to fire furnaces in the same sugar mill that yields about 8-10% ashes containing high amounts of un-burnt matter, silicon, aluminum, iron and calcium oxides. But the ashes obtained directly from the mill are not reactive because of these are burnt under uncontrolled conditions and at very high temperatures. The ash, therefore, becomes an industrial waste and poses disposal problems.

TABLE III: Properties of Bagasse Ash

S. No.	Property	Value
1	Specific Gravity	2.48
2	Atterberg's Limits	
	i) Plasticity index (%)	NP
3	Grain Size Distribution	
	i) Sand Size Particles	29(%)
	ii) Silt & Clay Size Particles (%)	71
4	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.33
	ii) Optimum Moisture Content (%)	17.1

C. Phosphogypsum

The production of phosphoric acid from natural phosphate rock by means of the wet process gives rise to an industrial by-product named phosphor gypsum (PG). About 5 tonnes of PG are generated per tonne of phosphoric acid production, and worldwide PG generation is estimated to be around 100-280 Mt per year. Most of this by-product is disposed of without any treatment, usually by dumping in large stockpiles. These are generally located in coastal areas close to phosphoric acid plants, where they occupy large land areas and cause serious environmental damage. PG is mainly composed of gypsum but also contains a high level of impurities such as phosphates, fluorides and sulphates, naturally occurring radionuclides, heavy metals, and other trace elements. All of this adds up to a negative environmental impact and many restrictions on PG

III. LABORATORY EXPERIMENTATION

All the geotechnical properties were tested based on Indian Standard procedures. The soil was initially air dried prior to the testing. The tests were conducted in the laboratory on the marine clay to find the properties of virgin marine clay and also adding different percentages of baggase ash and Phospho Gypsum with a view to determine the optimum percentage and also the effect on strength characteristics of marine clay by conducting various laboratory tests.

A. Index Properties

Liquid Limit, Plastic Limit of the untreated and treated expansive soil were determined by following Standard procedures as per IS: 2720 (Part-5)-1985; IS: 2720 (Part-6)-1972. Specific Gravity test were determined by using Pycnometer bottle method as per IS 2720 Part III.

B. Compaction Properties

Optimum Moisture Content and Maximum Dry Density for marine clay blending with different percentages of baggase ash and phospho gypsum were mixed with a view to determine optimum percentages by conducting I.S heavy compaction test as per IS: 2720 (Part VIII).

C. California Bearing Ratio (CBR) Tests

Samples were prepared for CBR test using expansive soil material mixing with different percentages of admixes baggase ash and phospho gypsum with a view to determine optimum percentages. The unsoaked and soaked CBR tests were conducted in the laboratory for all the samples as per IS Code (IS: 2720 (Part-16)-1979) as shown in the Fig.4

D. Unconfined Compression Strength Test (UCS):

The Unconfined Compression Strength Tests were conducted in the laboratory as per IS Code (IS: 2720, Part X (1991). Unconfined compressive strength is one of the most widely referenced properties of stabilized soils. For strength testing, specimens are generally tested at their maximum dry density and optimum moisture content. The strain rate was kept 1.2 mm/min in all the experiments. The proving ring of capacity 2 kN was used for testing specimens as shown in the Fig.5.

IV.RESULTS AND DISCUSSIONS

The details of various laboratory experimentation results are presented in the following section.

Table IIII: Test Results Of Marine Clay With Different Percentages Of Bagasse Ash

BA (%)	LL (%)	PL (%)	MDD (g/cc)	OMC (%)	CBR (%)	UCS (kPa)

0	72.8	27.2	1.36	29.5	1.4	72
10	70.5	27.7	1.38	29.2	2.3	81
20	69.2	28.3	1.41	28.8	3.6	89
30	67.7	29.2	1.39	28.4	2.8	87
40	65.3	29.9	1.37	28.1	2.5	84

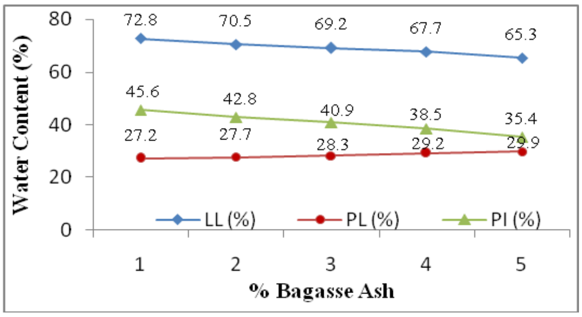

Fig. 1 Variation in Atterberg's Limits with % Bagasse Ash

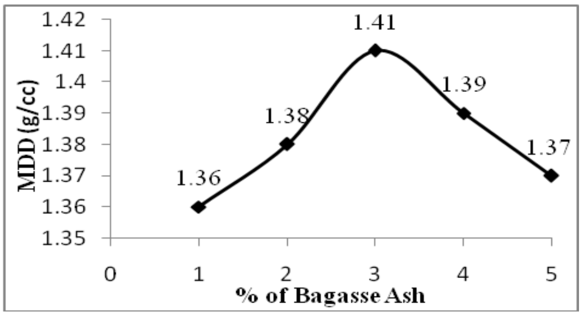

Fig.2 Variation in MDD with % Bagasse Ash

Fig.3 Variation in OMC with Different % Bagasse Ash

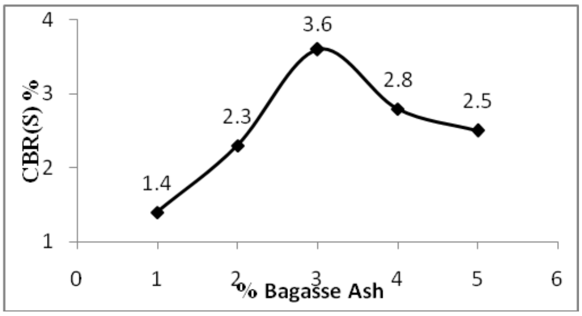

Fig.4 Variation of Soaked CBR Values with % Bagasse Ash

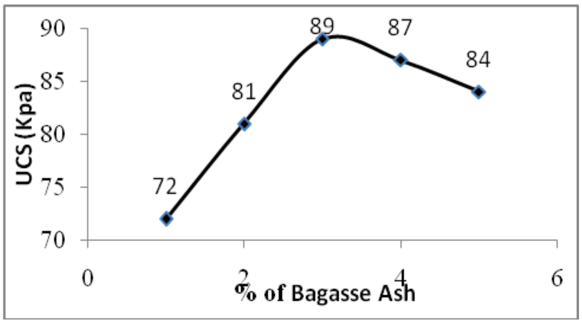

Fig.5 Variation in UCS with % of Bagasse Ash

A. Effect of Bagasse Ash on Geotechnical Properties of the Marine Clay: The individual influence of Bagasse Ash blending with different percentages in marine clay improves the strength characteristics as shown in the Figs.1 to 5 and Table.3. When the Bagasse Ash blending with marine clay at 0%, 10%, 20% 30% and 40%, the liquid limit values reduced from 72.82% to 65.5% and plastic limit values are increased from 27.2% 29.9% respectively as shown in the Fig.1.Compaction parameters like dry density increased from 1.36 to 1.41 g/cc up to 20% addition of Bagasse Ash and beyond it decreases where as optimum moisture content continuously decreases as shown in the Figs. 2 &3. Soaked CBR Values are increased from 1.4% to 3.6% up to 20% addition of Bagasse Ash and beyond it decreases as shown in the Fig.4. Unconfined strength values are increased from 72 kPa to 89 kPa and further addition of ash decreases the strength as shown in the Fig.5. From the above test results the optimum percentage of Bagasse Ash is 20%.

table IVv: TEST RESULTS OF MARINE CLAY WITH 20% BAGASSE ASH AND DIFFERENT PERCENTAGES OF PHOSPHO GYPSUM (PG)

PG (%)	LL (%)	PL (%)	MDD (g/cc)	OMC (%)	CBR (%)	UCS (kPa)
0	69.2	28.3	1.41	28.8	3.6	89
3	62.4	29.7	1.43	28.4	5.1	101
6	59.1	31.9	1.46	27.9	6.5	119
9	56.5	33.1	1.45	27.4	5.8	112

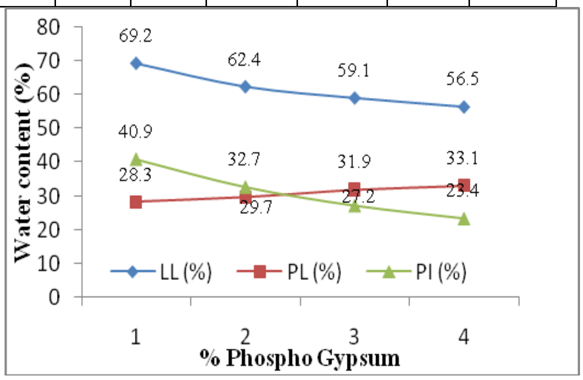

Fig. 6 Variation in Atterberg',s limits with Different % of Phospho Gypsum

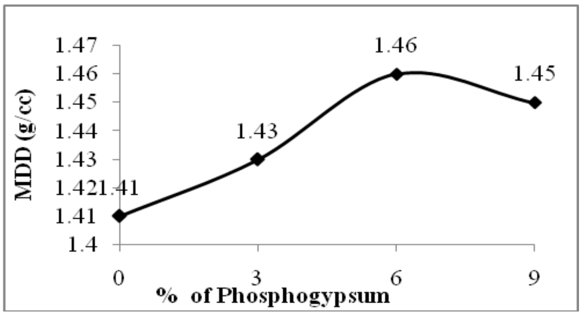

Fig.7 Variation in MDD with Different % of Phospho Gypsum

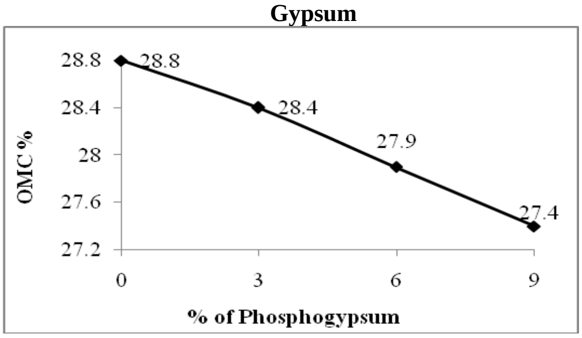

Fig.8 Variation in OMC with Different % of Phospho Gypsum

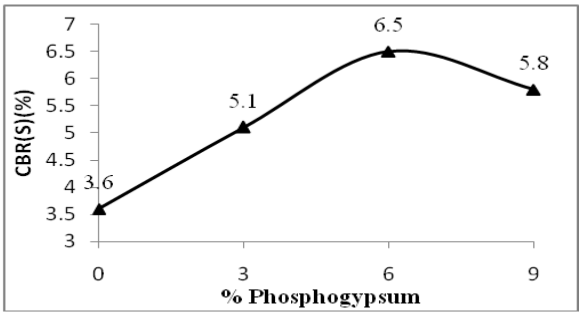

Fig.9 Variation in CBR with different % of Phospho Gypsum

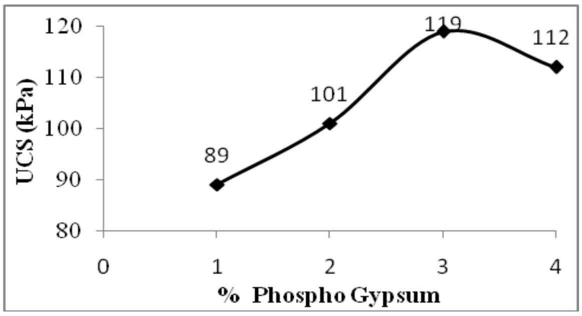

Fig.10 Variation of UCS Values with Different % of Phospho Gypsum

B. Effect of Optimum Percentage of Bagasse Ash with Different Percentages of Phospho Gypsum on Geotechnical Properties of the Marine Clay: Due to the addition of different percentages of Phospho Gypsum to the stabilized marine clay with bagasse ash the improvement in geotechnical characteristics as shown from Figs.6 to 10 and Table.IV. The liquid limit values reduced from 69.22% to 56.5 % and plastic limit values are increased from 28.3 % 33.1 % respectively as shown in the Fig.6 due to the addition of 0 %, 3 %, 6 % and of Phospho Gypsum respectively as shown in the Fig.6.Maximum dry density increased from 1.41 to 1.46 g/cc up to 6% addition of Phospho Gypsum and beyond it decreases where as optimum moisture content continuously decreases as shown in the Figs. 7 &8. Soaked CBR Values are increased from 3.6 % to 6.5 % and the unconfined strength values are increased from 89 kPa to 119 kPa up to the addition of 6% Phospho Gypsum and further addition of Phospho Gypsum decreases the CBR and UCS as shown in the Figs.9 and 10. From the above test results the optimum percentage of Phospho Gypsum is 6 %.

V. CONCLUSIONS

The following conclusions are made based on the laboratory experiments carried out in this investigation.

Marine Soil chosen was a problematic soil having high swelling, and high plasticity characteristics. It was observed that the treatment as individually with 20% of Bagasse Ash has moderately improved the marine soil. There is a gradual increase in maximum dry density with an increment in the % Replacement of BA up to 20% with an improvement of about 3.67% and it was about 10.3% for plasticity characteristics. There is an improvement in CBR, Shear parameters also by an amount of 23.6% for UCS and 157% for Soaked CBR respectively. Further addition of Phosphogypsum to the bagasse ash stabilized marine clay It can be inferred from the graphs, that there is a gradual improvement in the Plasticity index with an increment in % Addition of Phospho Gypsum (PG) up to 6% with an improvement of about 33.4%. Also maximum dry density is improved by an amount of 3.54% and it was about 33.7% for UCS and 80.5% for Soaked CBR respectively. It is evident that the addition of Bagasse Ash and Phospho Gypsum to the virgin Marine soil showed an improvement in properties of Marine Clay.

Finally it can be summarized that the materials Bagasse Ash and Phospho Gypsum had shown promising influence on the properties of Weak Marine soil, thereby giving a two-fold advantage in improving problematic Marine soil and also solving a problem of waste disposal.

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