EFFECT OF MOULDING WATER CONTENT ON THE STRENGTH BEHAVIOUR OF BLACK COTTON SOIL TREATED WITH BAGASSE ASH AND LIME

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Abstract - *Black cotton soil, expansive in nature posess problems in Civil engineering due to its intrinsic swelling and shrinkage behaviour. In the present, an experimental study is aimed to improve the shear strength of Locally available Indain Black cotton soil mixed with lime and bagasse ash and to analyse the behaviour of the soil- lime -bagasse ash mixtures at varying moulding water content for different curing periods. The effect of moulding water content on the strength behaviour of black cotton soil treated with lime and bagasse ash, varying from dry of optimum to wet of optimum condition is presented in the paper.. Water content, an important parameter in soil –lime-Bagasse ash mixtures and based on the experiments an increase in strength was noted in dry of optimum condition compared to the wet of optimum condition, attributed to pozzolonic reactions. In the process of densification, the clay particles structure changes from flocculated state to dispersed state on addition of water from dry of optimum to wet of optimum conditions.. The unconfined compressive strength of soil-lime –bagasse ash mixtures increased by 6.4, 6.0 and 10.4 folds for dry of optimum, optimum and wet of optimum conditions respectively on comparison with black cotton soil alone on curing for a period of 90 days. Thus, the results obtained in terms of strength increase is promising and a rational approach for utilization of bagasse ash for geotechnical applications can be developed.*

Key Words: Bagasse ash, moulding water content, unconfined compressive strength , black cotton soil

1. INTRODUCTION

The global dimension of the waste problem, the factors contributing being population, consumption, Affluence, technology and impact. The observation being made that 95% of the population growth would occur in developing countries (Morrison, 1999), rapid expansion in industrialization especially in developing countries affluence by high GDP growth. world bank reporting massive levels of industrial investments would occur in developing countries and the impact would be a 5 fold increase in global waste generation(Source: OECD, 2000). Industrial waste forms about 60% of the total wastes worldwide. The problem associated with this large quantum of waste is its disposal, the conventional method being landfills, but scarcity of land available poses a concern to develop an alternative method of waste disposal. The important strategy of waste management, being Reduce, Reuse and Recycling can be adopted to Recover the energy from these industrial waste and use as construction materials. With this concept,various wastes such as Agricultural waste, building construction industry waste, coal combustion residues, blast furnace slag, residue from cement kiln and others have been explored as stabilizing agents to improve the properties of problematic soils.

In a tropical country such as India, various soil deposits exist, throughout which large variation in engineering behaviour can be found. One among them is Black cotton soil, covering about 20% of land area in India. Black Cotton soils, expansive in nature, consists of Montmorillonite as a primary clay mineral. Expansion in soils results from the changes in the soil water system caused by the disturbance in the internal stress equilibrium. The present trend in Geotechnical engineering is to alter the engineering properties of the native problematic soils to meet the design specifications. There is a worldwide interest in these innovative research, knowledge transfer and best practice regarding the development of new ground improvement methods. one of the important emerging technologies of ground improvement methods being Soil stabilization, is a method adopted to improve shear strength, reduce permeability and reduce compressibility of the native soil. The simplest stabilization processes are compaction, drainage and improving gradation of particle size and further improvement can be achieved by adding binders to the weak soils (Rogers et al, 1996).

Sugarcane bagasse ash (SCBA) is a by-product obtained by combustion from sugar industries boilers. Once the process of juice extraction from crushing of sugarcane in sugar mills from prepared cane by milling, the remaining fibrous residue matter is termed as bagasse. Bagasse is generally used in boilers as fuel in the sugar mills for cogeneration process. The burnt bagasse in cogeneration boilers forms the bagasse ash is collected in bag-house filter and is dumped locally in the existing vacant land, thus posing a severe concern for the environment. Silica forms the major composition of bagasse ash and based on many literatures Bagasse ash can be considered as pozzolonic in nature. As it is seen, there are several prospective literature review mentioning about the utilization of this biomass waste in stabilised mud blocks, ash filters, ceramics and bricks, cement replacing materials. Hence, new possibilities in the domain of soil stabilization for problematic native soil is explored in the present study.

In the present, Experimental studies have been done to test for the role of addition of bagasse ash and lime on the behaviour of black cotton soil for various moulding water content with curing effect.

2. MATERIALS AND METHODS

2.1 Black Cotton Soil

Black cotton soil, a typically expansive clay , was collected at a depth of 1.5m from Butkurki village, Ramdurga Taluk, Belgaum district, India. The soil sample was oven dried, grounded in a ball mill and fine fraction passing through 425 micron BIS sieve was used in the experimental study.The physical and engineering properties of the soil are listed in Table 1.The soil being classified as sandy clay of high compressibility (CH) as per Unified soil classification system (USCS).

Table -1: Basic properties of Black cotton soil

Type of test	**Values**
Colour	Dark grey
Specific Gravity	2.61
Liquid limit (%)	72.01
Plastic limit (%)	39.06
Plasticity Index (%)	33.00
Shrinkage limit (%)	9.36
Sand fraction (%)	11.00
Silt fraction (%)	44.00
Clay fraction (%)	45.00
Maximum dry density (kN/m^3)	14.00
Optimum moisture content (%)	33.00

2.2 Sugarcane Bagasse Ash

Sugarcane bagasse ash (BA) was obtained from Mandya sugarcane Factory, Mysore district, Karnataka, India. Sugarcane bagasse ash was burnt in controlled temperature conditions for 400^0 C for 2 hours to remove the unburnt carbon present and the bagasse ash so the generated material is likely to contain amorphous silica which is known to possess pozzolanic properties. After burning BA, it is grounded and fraction passing through 425 micron BIS sieve was used in the present investigation. The physical and engineering properties of the BA are listed in Table 2.

Table 2. Basic properties of Bagasse ash

Properties	**Values**
Specific Gravity	1.5
Liquid limit (%)	35.2
Plastic limit (%)	NP
Plasticity Index (%)	NP
Shrinkage limit (%)	23.4
Loss on Ignition(%)	18.2
Fineness Modulus	11.5
Amorphous Silica as SiO_2(%)	66.9
Alumina as Al_2O_3(%)	4.4
Calcium as CaO(%)	1.4

2.3 Hydrated lime

Pure hydrated lime Ca(OH)2 with 99% purity, which is available commercially was obtained from Vasu scientific house, Bengaluru was used in this work.

2.4 Methods

Mini compaction test apparatus, developed by Sridharan and Sivapullaiah (2005), was used for the compaction studies. Unconfined compressive strength tests were conducted in accordance to BIS: 2720 (part X) (1973), for various combinations of black cotton soil bagasse ash and lime mixtures. The prepared soil admixture samples were compacted corresponding to the respective maximum dry density and optimum moisture content for dry of optimum, optimum and wet of optimum conditions. These samples were stores in airtight polyethylene covers and kept in the desiccators for 100% humidity to be maintained for long term curing periods and prevents moisture entry to the samples. The experimental programme has been planned to study the role of moulding water content on the strength behaviour of expansive black cotton soil treated with optimum percentages of Bagasse ash and lime for immediate and with curing period up to 90 days for strength behaviour at different moulding water content such as dry of optimum, optimum and wet of optimum conditions. The optimization of 20% Bagasse ash and 3% lime for black cotton soil have been arrived based on the unconfined compressive strength tests.

3. RESULTS AND DISCUSSION

3.1 Compaction behavior of soil with bagasse ash and lime at different moulding water content

The compaction tests were conducted on black cotton soil and bagasse ash respectively. Further on, compaction tests were also conducted black cotton soil with optimum amount of bagasse ash and lime treated for dry of optimum, optimum and wet of optimum conditions. The dry density and water content at dry of optimum, optimum and wet of optimum conditions have been obtained on the basis of compaction test results of the respective combinations on either side of the compaction curve as shown in the Fig 1. The water contents corresponding to 95% of maximum dry density were chosen on dry side and wet side of optimum as shown in the Fig. 1

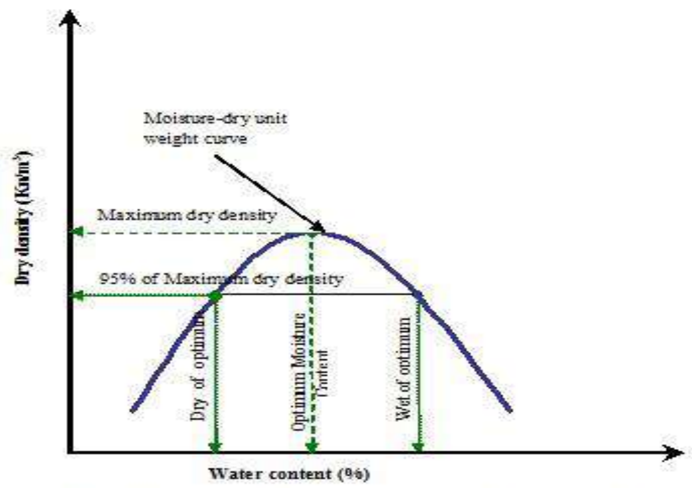

Fig -1. Dry-density moisture content relationship for a particular compactive effort

Table 4. Selected dry density and corresponding water contents on dry of optimum, optimum and wet of optimum from compaction tests

Mixture	Dry of Optimum		Optimum		Wet of Optimum	
	Density (kN/m³)	W/C (%)	Density (kN/m³)	W/C (%)	Density (kN/m³)	W/C (%)
BCS	14.0	26.0	14.7	31.0	14.0	34.8
BA	11.6	14.4	12	20.3	11.6	24.4
BCS+3% Lime	14.72	24.0	15.5	26.5	14.72	29.0
BCS+ 3%Lime+ 20%BA	13.3	20.0	14.0	23.0	13.3	25.0

With the addition of lime to Black Cotton soil, the strength increase for both immediate as and for various curing periods. This is because of formation of cluster due to the addition of lime in black cotton soil up to optimum percentage. Hence 3% of lime was considered as optimum for the black cotton soil. With the addition of various percentages of bagasse ash to lime treated black cotton soil, strength tests were conducted for immediate effect as well as with curing periods and 20% of bagasse ash for lime treated black cotton soil was found to be optimum percentage. Unconfined compressive strength tests were carried out for lime treated black cotton soil with bagasse ash at dry of optimum, optimum and wet of optimum conditions respectively for 0, 7, 30, 90 days of curing periods and the results are presented.

3.2 Effect of moulding water content on the Black cotton soil-lime-bagasse ash mixtures for various curing periods.

3.2.1 Dry of optimum condition

The unconfined compreesive strength of Black cotton soil-lime-bagasse ash mixture has shown an increasing trend with increase in curing period and reached the value of 1861.2 kPa after 90 days of curing period, indicating that the strength increased by 6.4 folds compared to black cotton soil alone as shown in Fig.2 and Table 5. The increase in unconfined compressive strength for lime treated BCS with bagasse ash is attributed to the pozzolonic reaction between the lime and bagasse ash, producing a compound termed as calcium silicate hydrates and calcium aluminate hydrates

Table 5. Strength of Black cotton soil-lime-bagasse ash mixtures on dry of optimum condition for various curing period

Mixture	Unconfined compressive strength for dry of optimum condition(kPa)				
	Curing period in days				
	0	**7**	**30**	**60**	**90**
BCS	290	290	290	290	290
BCS+3% Lime	623	1116	1214	1358	1398
BCS+3% Lime+20%BA	853	1190	1307	1467	1861

3.2.2 Optimum condition

The unconfined compressive strength of Black cotton soil-lime-bagasse ash mixture has shown an increasing trend with increase in curing period and reached the value of 1412 kPa after 90 days of curing period, indicating that the strength increased by 6 folds as compared to black cotton soil alone as shown in Fig.2 and Table 6. The increase in strength is due to reaction between lime treated BCS and bagasse ash having calcium concentration and pH of the pore fluid will increase.

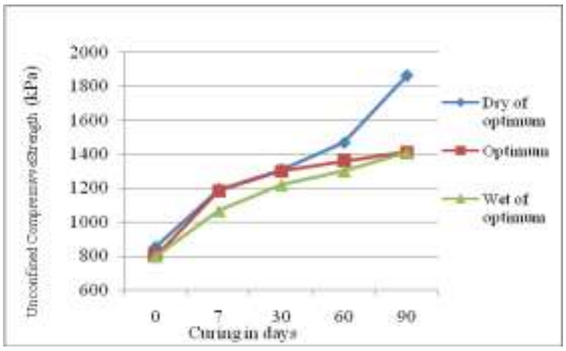

Fig-2. Effect of moulding water content on the strength of Black cotton soil-lime-bagasse ash mixtures for various curing periods

Table 6. Strength of Black cotton soil-lime-bagasse ash mixtures on optimum condition for various curing period

Mixture	Unconfined compressive strength for optimum condition(kPa)				
	Curing period in days				
		7	**30**	**60**	**90**
BCS	234	234	234	234	234
BCS+3% Lime	612	866	1018	1163	1198
BCS+3% Lime+20%BA	799	1183	1300	1358	1412

3.2.3 Wet of optimum condition

The unconfined compressive strength of Black cotton soil-lime-bagasse ash mixture has shown an increasing trend with increase in curing period and reached the value of 1406kPa after 90 days of curing period, indicating that the strength increased by 10.4 folds compared to black cotton soil alone as shown in Fig.2 and Table 7. The increase in unconfined strength Black cotton soil-lime-bagasse ash mixture is due to cation exchange and flocculation of particles on the addition of bagasse ash to lime treated black cotton soil. This may be due to more water which is available at wet of optimum condition which enhances the pozzolanic reaction for long term curing at higher water content.

Table 7. Strength of Black cotton soil-lime-bagasse ash mixtures on wet of optimum condition for various curing period

Mixture	Unconfined compressive strength for wet of condition(kPa)				
	Curing period in days				
	0	**7**	**30**	**60**	**90**
BCS	135	135	135	135	135
BCS+3% Lime	440	644	872	987	1014
BCS+3% Lime+20%BA	797	1066	1218	1300	1406

The Effect of moulding water content on the increase in unconfined compressive strength of Black cotton soil-lime-bagasse ash mixtures for various periods of curing is presented in Fig.3. It is evident that, the strength increases by 10.4 folds with respect of BCS alone at wet of optimum as compared to 6.4 folds at dry of optimum and 6.0 folds at optimum conditions.

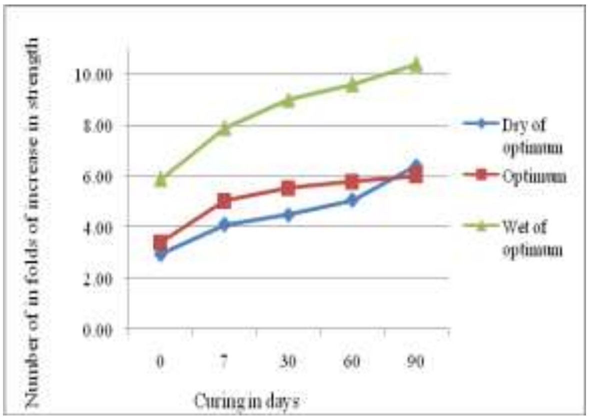

Fig-3. Variation of increase in strength of Black cotton soil-lime-bagasse ash mixtures for various curing periods

3.3 Effect of moulding water content on the strength ratio of Black cotton soil-lime-bagasse ash mixtures

The strength ratio is defined as the ratio of the strength of mixture with curing to that of strength without curing, compacted at the same water content and respective dry densities.

The strength of black cotton soil increases on addition of optimum percentage of bagasse ash compacted at all the moulding water contents compared to that of black cotton soil alone with immediate testing and curing periods, this is due to predominant amount of coarser particles of bagasse ash. It is observed that the strength of BC soil-bagasse ash mixture compacted at dry of optimum condition is higher than optimum and wet of optimum conditions as shown in

Table 4. This is attributed to loss of cohesion is greater than the effect of increased density for cohesive soil

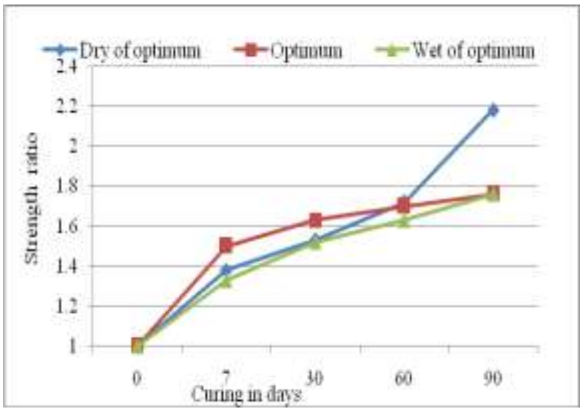

Fig-4. Effect of moulding water content on the strength ratio of Black cotton soil-lime-bagasse ash mixtures for various curing periods

The increase in strength of black cotton soil and optimum lime and bagasse ash mixture with curing occurs due to flocculation of particles on dry side of the optimum and development of pozzolanic reaction compounds within the available water the strength increases. The strength ratio is 2.18 at dry of optimum, 1.76 at optimum and 1.76 at wet of optimum conditions on 90 days curing period as shown in Fig 3. The relatively higher rate of strength gain is observed on samples compacted on dry of optimum than samples compacted at optimum and wet of optimum conditions.

4. CONCLUSIONS

The following conclusions were drawn based on the experiments and analysis:

- The strength of Black cotton soil-lime-bagasse ash mixtures increases with increase in curing period for all the moulding water contents. However, higher strength was observed in dry of optimum condition compared to optimum and wet of optimum conditions.

- Unconfined compressive Strength of Black cotton soil-lime-bagasse ash mixture increases with increase in period of curing for all the moulding water contents. Addition of optimum baggase ash to lime treated BCS, strength increased by 6.4 folds, 6.0 folds and 10.4 folds for dry of optimum, optimum and wet of optimum conditions respectively compared to BCS alone after 90days of curing.

- The relatively higher rate of strength gain of Black cotton soil-lime-bagasse ash mixture with respect to black cotton soil alone. is observed on samples compacted on wet of optimum than samples compacted at optimum and dry of optimum conditions.

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