International Journal of Civil Engineering (IJCE)
ISSN(P): 2278-9987; ISSN(E): 2278-9995
Vol. 7, Issue 5, Aug - Sep 2018; 13-22

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

EXPERIMENTAL STUDIES ON THE EFFECT OF SUGARCANE BAGASSE ASH-LIME ON THE PHYSICAL AND MECHANICAL PROPERTIES OF MONTMORILLONITIC SOIL

Nethravathi. S[1], Ramesh. H. N[2], Udayashankar. B. C[3]&Vittal. M[4]

[1,3]Department of Civil Engineering, R V College of Engineering, Bengaluru, Karnataka, India

[2,4]Faculty of Engineering-Civil, University Visweswariah College of Engineering, Bengaluru, Karnataka, India

ABSTRACT

Industrial waste generated is a major contributor of total waste worldwide. The proper mechanism for management of these waste needs to be established, especially in developing countries. The conventional method of disposing these waste in landfills has to be supplanted to recycling and exploring the beneficial effects of these waste and use as a construction material. Sugarcane bagasse ash is an agro industrial residue, posing an environmental concern of due to its disposal in landfills and as an air pollutant. With this aspect, the bulk utilization of Sugarcane bagasse ash of geotechnical applications such as embankments/dykes, foundations, roadways in the form of backfill material, sub-base material along with soil is studied. Soil stabilization aims at improving the properties of soil can be attained by methods of Compaction, soil replacement, addition of Chemicals, soil reinforcement. In this paper, an effort to utilize the sugarcane bagasse ash in addition with lime is made to improve the geotechnical properties of locally available Indian Expansive soil. The experimental studies on addition of various percentages of bagasse ash and lime by dry weight to Expansive soil is conducted and the important geotechnical properties such as Index properties, Compaction, Strength and compressibility behavior are analyzed. On the basis of test results, it can be concluded that Sugarcane bagasse ash with lime can be used for soil stabilization, which embarks the inclusive technology of marching towards sustainability.

KEYWORDS: *Sugarcane Bagasse Ash, Black Cotton Soil, Industrial Waste, Properties of Soil*

Article History

Received: ***26 Jul 2018* | *Revised:* *03 Aug 2018* | *Accepted:* *28 Aug 2018***

INTRODUCTION

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, consist 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 factors influencing the shrink-swell potential of a soil can be considered in three different groups, the soil characteristicsthat influence the basic nature of the internal force field, the environmental factors that influence the changes that may occur in the internal force system, and the state of stress (Nelson& Miller). The present trend in Geotechnical engineering is to alter the engineering properties of the native problematic soils to meet the design specifications. One of the important emerging technologies of ground improvement methods being Soil stabilization, aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or combination of the two (*Sherwood, 1993*). 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*). In chemical stabilization, it depends mainly on chemical reactions between stabilizer (cementitious material) and soil minerals (pozzolanic materials) to achieve the desired effect. The stabilized soil materials have a higher strength, lower permeability and lower compressibility than the native soil.

Next to Brazil, India is the second largest producer of sugarcane in the world with the annual production in the year exceeded 300 million tonnes. It is estimated that the processing of this quantity of sugarcane in sugar mills results in the production of approximately 100 million tonnes of wet bagasse annually. Sugarcane bagasse is the fibrous matter that remains as a residue after sugarcane stalks are crushed to extract their juice. A typical chemical analysis of bagasse are: Cellulose-45-55%, hemicelluloses-20-25%, lignin-18-24%, ash-1-4%,waxes-,1%. Bagasse ash, the residue obtained whenbagasse is burnt as a fuel in sugar mill boilers, is known to posesspozzolanic properties, but unfortunately due to lack of awareness most of it is disposed in landfills. When left in the open, it ferments and decays, thus necessitating the safe disposal of the pollutant. Also, when the pollutant is inhaled in large doses, it can cause a respiratory disease known as Bagassiosis (*Laurianne 2004*). Bagasse ash is presently used as a biofuel and in the manufacture of pulp and paper products and building materials. Recently, sugarcane bagasse ash has been tested in some parts of the world for its pozzolanic property. Few studies have been reported on the use of bagasse ash as partial cement replacement material in respect of cement mortars. With this background, an effort has been made to study the behaviour of bagasse ash as a stabilizer for Expansive soils.

MATERIALS AND METHODS

Black Cotton Soil

Black cotton soil is a typically expansive clay soil containing Montmorillonite as its chief mineral constituent and was collected at a depth of 1.5m from Butkurki village, RamdurgaTaluk, Belgaum district, India. To ensure the uniformity of the soil sample it was oven dried, pulverized and sieved through 425 micron BIS sieve before used in the present investigation. The physical and engineering properties of the soil are listed in Table 1. The soil is classified as sandy clay of high compressibility (CH) as per Indian Standard classification system (ISCS)

Bagasse Ash

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 generated is likely to contain amorphous silica which is known to possess pozzolanic properties. After burning BA, it is pulverized and 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 1: Basic Properties of Black Cotton Soil

Type of Test	Values
Colour	Darkgrey
SpecificGravity	2.61
Liquidlimit (%)	72.01
Plastic limit (%)	39.06
Plasticity Index (%)	33.00

Table 1: Contd.,

Shrinkagelimit (%)	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
Unconfined compressive strength(kPa)	134.00

Table 2: Basic Properties of BA

Properties	Values
Specific Gravity	1.55
Liquid limit (%)	35.20
Plastic limit (%)	NP
Shrinkage limit (%)	23.40
Loss on Ignition (%)	18.20
Amorphous Silica as SiO_2(%)	66.91
Alumina as Al_2O_3(%)	4.44

Lime

Commercially available pure hydrated lime $Ca(OH)_2$ with 99% purity was used in this work.

Experimental Program

In the present investigation, Bagasse ash used possess low Calcium oxide content (CaO), hence in order to increase its cementations properties, lime has been added. Bagasse ash and lime used in the present study are in percentage by weight of the soil. The optimum percentage of Bagasse ash and lime content to beadded to black cottonsoil have been determinedbased on the unconfined compressive strength.The optimization of Bagasse ash in black cottonsoil has been determined by adding 10 - 60% of Bagasse ash of black cottonsoil and itwasfoundthat 20% of Bagasse ash of black cottonsoilto be optimum. The addition of 4% of lime wasfound to be optimum for black cottonsoil - Bagasse ash mixture.The soil samples of black cotton soil-bagasse ash treated with optimum lime percentage were prepared at a maximum dry density (MDD) and optimum moisture content (OMC).

The testing methods were conducted as per BIS: 2720 (Part V) -1985 for liquid limit by using the cone penetration method, BIS: 2720 (Part VI) -1985 for plastic and BIS: 2720 (Part VI) -1972 for shrinkage limit determination for various combinations of black cotton soil- bagasse ash lime mixtures. Compaction tests were conducted using mini compaction test apparatus as per the procedure of Sridharan and Sivapullaiah [2005]4, Unconfined compressive strength tests were carried out as per BIS: 2720 (part X) [1973]6, for various combinations of lime treated black cotton soil with bagasse ash. All samples were prepared at their respective maximum dry density and optimum moisture content. The prepared samples were kept in airtight plastic bags and kept in the desiccators and maintained 100% humidity for prolonged curing periods in such a way that there is no moisture movement.

RESULTS AND DISCUSSIONS

Effect of Bagasse Ash and Lime on the Index Properties of Black Cotton Soil

In case of highly plasticity mineral, montmorillonite the liquid limit is primarily governed by the thickness of the diffused double layer (Sridharan et al, 1986). Bagasse ash particles contain no negatively charged clay minerals, its liquid limit being controlled by the shearing resistance at particle level as in the case of silty soils. As seen from the Table 3, on increasing the amount of Bagasse Ash to Black cotton soil, the liquid limit reduces. On further increase of bagasse ash up to 60%, the liquid limit of BCS gradually decreases. Increasing bagasse ash content to the BCS, the alterations in the liquid limit of the BCS are due to the following factors:

Reduction in the diffused double thickness of clay particles by increasing the electrolyte concentration and by exchanging monovalent cation by divalent calcium ions. In case of highly plastic mineral, montmorillonite, the category of exchangeable cation exerts a restraining impact over the amount of expansion that takes place in the presence of water. Increasing caton valence decreases the liquid limit of expansive soils. (Mitchell)

The effect of bagasse ash as a diluent, reduces the liquid limit of black cotton soil because it is coarser than the BCS and it reduces the amount of soil to be flocculated.

Since the specific gravity of bagasse ash is relatively of lower value compared to that of the BCS, it acts as a better diluent. Addition of lime, to BCS-BA mixture decreases the liquid limit as observed in the Table 3. This is attributed to the effect of depletion in the extent of diffused double layer and/or effect of dilution.

The alteration of plastic limit of Black Cotton Soil mixed with various different quantities of Bagasse ash at different curing period is as shown in Table 6. Initially with the addition of Bagasse ash, a coarser material to Black cotton soil, tends to increase the plastic limit. However, with the increasing addition of Bagasse ash to Black cotton soil, marginal changes in the plastic limit is observed. With the increasing addition of BA to BCS, the quantum of soil to be flocculated reduces. The finer particles of BA may be induced in the voids of flocculated soil thereby decreasing the water held in the pores which leads to decrease in the plastic limit.As the percentage of BA to BCS has increased over 40%, the mixture tends to be non-plastic. With the rise in percentage of BA, a non-plastic coarser matter, the activity of clay is decreasing causing a reduction in plastic limit. With increase in percentage of lime, the plastic limit of BCS-BA mixture reduces due to a reduction in the diffused double layer thickness. Uponcuring, the decrease is marginal due to reduction in the percentage of flocculated soil and the rate of flocculation reduces due to lower lime content.

As seen from the Table 3, addition of BA increases the shrinkage limit of BCS. The shrinkage limit of clays increases with solid wastes, which is an indicative of a reduction in swelling-shrinkage potential.The increase in the shrinkage limit with the increase in Bagasse Ash is mainly attributed to the substitution of finer particles of BCS by coarser BA particles. As BA contains lower lime content, the flocculating of lime accounting for increasing the shrinkage limit is relatively less and is overridden by the coarseness of BA particles. The addition of lime to BCS-BA mixture significantly increases the shrinkage limit. Thus, the theory that the free lime influence of flocculation is more dominant than due to the effect of addition of coarser material is proved.

Table 3:Atterberg'sLimits of Black Cotton Soil with Bagasse Ash and Lime

Mixture	Atterberg'sLimit		
	Liquidlimit (%)	Plasticity Index	Shrinkagelimit (%)
BCS alone	83.0	47.0	9.4
BA alone	63.0	NP	NA
BCS+20%BA	78.0	39.0	14.0
BCS + 20%BA+4% Lime	57.8	25.9	32.0

Effect of Bagasse Ash and Lime on Compaction Behaviour of Black Cotton Soil

The strength of the soil can be enhanced by densification by compaction. However, when adequate mechanical stability cannot be obtained even with the increase in compactive effort or when the enhanced strength or resistance to water softening is required, admixtures for stabilization combined with compaction becomes necessary. Hence, the compaction behaviour of BCS on the addition of bagasse ash and lime has been studied.

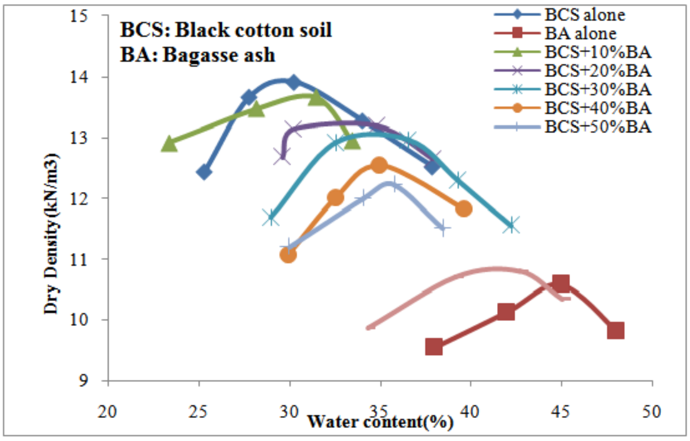

Figure 1: Dry Density–Water Content of Black Cotton Soil Treated with Bagasse Ash

Figure 1 shows the compaction test results of the Black Cotton Soil treated with 10% to 60% bagasse ash. From the compaction tests it was found that Maximum dry density (MDD) of the black cotton soil decreases and the optimum moisture content(OMC) increases, with the addition of bagasse ash and lime. The reduction in maximum dry density may be attributed to the replacement of bagasse ash in the soil mixture which has a relatively lower specific gravity than that of soil and needs a lower comp active energy to attain its maximum dry density (Osula 1991). The decrease in maximum dry density may also be attributed to the flocculation and agglomeration of soil particles with thelarge void spaces replaced by bagasse ash leading to a corresponding decrease in maximum dry density (Ola 1977). The increase in optimum moisture content is probably a consequence of the additional water held within the flocculent soil structure resulting from the bagasse ash interaction and the increased water absorption by the soil- bagasse ash mixture as a result of its lower specific gravity.

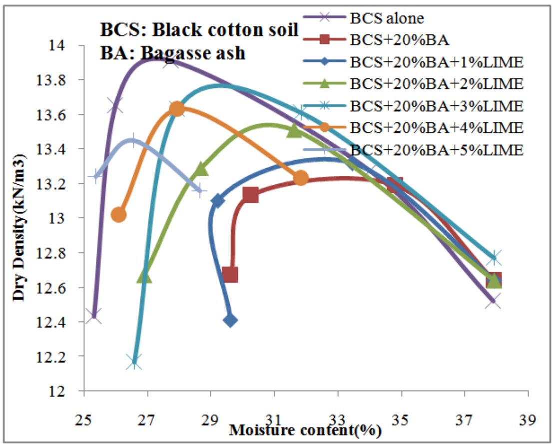

Figure 2: Dry Density–Water Content of Black Cotton Soil -Bagasse Ash Mixtures with Lime

The optimization of lime soil mixtures has been created by adding various percentage of lime to the black cotton soil. On addition of 1% to 5% of lime to the black cotton soil, the maximum dry density increased up to 4% with adecrease in optimum moisture content as seen in the Figure 2.Beyond 4% of lime, the dry density of soil mixtures decreases with an increase in optimum moisture content. This is due to the increased flocculation and agglomeration of soil particles having large void space occupied by lime (Ola, 1978) with increase in availability of lime content. This would increase the repulsive forces of the soil particles, thereby increasing the resistance to compactive effort. The increase in OMC of expansive clays treated with lime may be caused by flocculation so that when compacted the soil each have an increased volume of voids compared with untreated soil, in addition the increase in hydroxyl ions liberated by lime, increases the affinity of the surfaces of clay particles for water (Bell, 1987).

Effect of Lime and Bagasse Ash on Unconfined Compressive Strength Behavior of Black Cotton Soil

The tests were conducted on strength properties as to determine the Optimum amount of bagasse ash and lime to be added to black cotton soil by unconfined compression Strength test. On addition of10% to 60% of bagasse ash to the black cotton soil, the strength increases up to 20% of bagasse ash addition on immediate testing as well as with increased curing periods due to decrease in diffuse double layer thickness and flocculation of the clay particles.

The decrease in the strength of black cotton soil treated with bagasse ash beyond 20% additionmay be because ofthe matrix of the black cotton soil is disturbed more and more with the increase ofbagasse ash. Hence, 20 % addition of bagasse ash to the black cotton soil has been chosen as the optimum percentage. The variation of unconfined compressive strength of black cotton soil treated with various percentages of bagasse ash for immediate and 7 days curing period are shown inFigure 3.

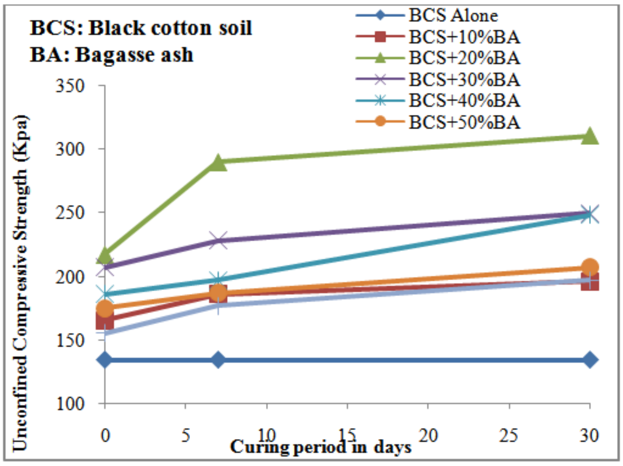

Figure 3: Variation of UCS of Black Cotton Soil -Bagasse Ash Mixtures with Curing

Addition of various percentages of lime to the black cotton soil treated with optimum percentage of bagasse ash the strength increases up to 4% in addition of lime, there after strength decreases with the increase in the percentage of lime on the immediate testing and curing period.The increase in strength up to 4% in addition of lime may be due to pozzolanic reactions between reactive silica and free lime. Effective penetration of lime and the formation of new cementitious products such as calcium silicate hydrate and calcium aluminium hydrate (C-S-Hand C-A-H), binds the soil particles together (Narasimha Rao, 1997). Hence 4% of lime to black cotton soil and bagasse ash mixture has been chosen as optimum lime content for the mixture.The variation in strength of the black cotton soil treated with optimum percentages of bagasse ash for Immediate, 7 and 30 days curing period with various percentages of lime are shown in the Figure 4.

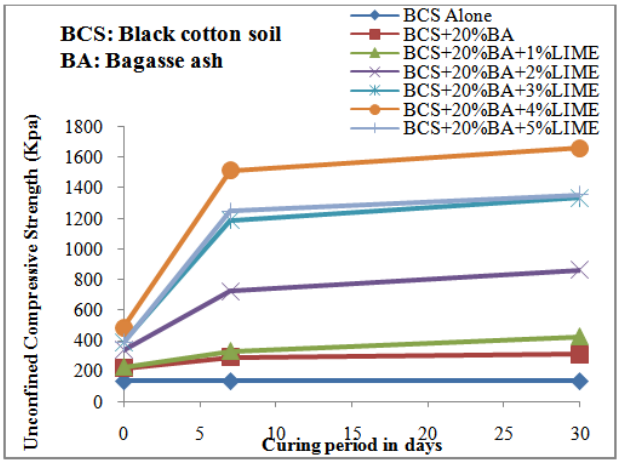

Figure 4: Variation of UCS of Black Cotton Soil -Bagasse Ash Mixtures with Lime with Different Curing Time

Unconfined compressive strength tests were conducted on expansive soils treated with bagasse ash and lime and the effect of curing is presented in Table 3. On addition of 20% bagasse ash to the black cotton soil alone, the UCC strength increased from 217.36kpa to 512kpa for 0 to 60 days testing respectively. Figure 5 shows the variation of strength ratio v/s curing period in days. The strength ratio of BCS alone for the optimum condition is 1. It remained constant for the different curing period conditions because there was no addition of chemicals, therefore there is no reactions in the strength ratio. On addition of 20% bagasse ash to the black cotton soil alone, the strength ratio increased from 1 to 2.36 for60 days testing respectively This was may be due to the pozzolanic reactions between reactive silica and free lime and also due to the effective penetration of lime in which the formation of new compounds i.e., cementitious compounds (C-S-H and C-A-H) takes place, which binds the black cotton soil and lime effectively.

Table 4: Strength of BCS with BA and Lime Mixtures with Various Curing Period

Mixture	Curing period in Days				
	0	7	30	45	60
	Unconfined compressive strength (kPa)				
BCS alone	134	134	134	134	134
BCS+20%BA	217	290	311	432	512
BCS+20%BA+4%LIME	485	1513	1662	1699	1781

With addition of 4% lime to the black cotton soil and optimum bagasse ash mixtures, the UCC strength increased from 485kpa to 1781kpa for 0 to 60 days testing respectively. The increase in strength was due to the decrease in diffused double layer thickness and flocculation of clay particles.On addition of 4% lime to the black cotton soil and optimum bagasse ash mixtures, as shown in Table 5. The strength ratio increased from 1 to 3.67 for 0 to 60 days testing respectively. The increase in strength ratio was due to the decrease in diffused double layer thickness and flocculation of clay particles.

Table 5: Strength Ratio of BCS with BA and lime Mixtures with Various Curing Period

Mixture	Curing period in Days				
	0	7	30	45	60
	Strength Ratio				
BCS alone	1.00	1.00	1.00	1.00	1.00

Table 5: Contd.,

BCS+20%BA	1.00	1.33	1.43	1.99	2.36
BCS+20%BA+4%LIME	1.00	3.12	3.43	3.50	3.67

BCS: Black cotton soil BA: Bagasse ash

CONCLUSIONS

Based on the results of the experiment and analysis, the following conclusions have been drawn:

- Inclusion of Bagasse ash and lime significantly affect the index properties of BCS, dependsupon the amount of bagasse ash.Theeffect of bagasse ashismainlycaused bythesubstitution of finesoilparticles by coarse bagasse ashparticles.The influence of lime on the properties of montmorillonitic soilisexplainedbased on itseffect of diffused double layer thickness of clayparticles and on the fabric of soil.
- Maximum dry densitydecreases and optimum moisture content increases for expansive black cottonsoiltreatedwithvariouspercentages of bagasse ash. This may be due to the low density of bagasse ash replace witha high density of soil, results in the decrease of the specificgravity.
- The addition of variouspercentages of bagasse ash to expansive black cottonsoil the strengthincreaseswithan increase in the curingperiod. The maximum strengthwasobserved at 20% (by weight of soil) bagasse ash addition to the black cotton soil for 30 days of curingperiod. Hence, 20% bagasse ash to the black cottonsoilwasconsidered as an optimum percentage.
- Upon addition of variouspercentages of lime to the black cotton soil the strengthincreaseswithincrease in curingperiod. The maximum strengthwasobserved at 4% lime addition for expansive soil. Hence, 4% of lime content for the soilisconsidered as optimum percentage.
- In the design of flexible pavements, the subgradestrengthis a vital parameter. Hence, an indication of the increase in strength ratio of expansive soilwith bagasse ash and lime withcuring, suggests the utilization in pavements on expansive soil.

REFERENCES

1. *Aigbodion, V.S., Hassan, S.B., Ause, T. and Nyior, G.B. 2000.Potential Utilization of Solid Waste (Bagasse Ash) Journal of Minerals&MaterialsCharacterization& Engineering, Vol.9, pp 67-77*
2. *Bell, F.G. (Ed) (1987), GroundEngineers Reference Book, Buttersworth Publication (1987).*
3. *BIS 2720 (Part VII) (1980).Determination of Light compaction. Bureau of Indian Standards, New Delhi.*
4. *BIS 2720 (Part X) (1973).Determination of Unconfined Compressive Strength, Bureau of Indian Standards, New Delhi.*
5. *John Nelson, Debora J. Miller(1992)Expansive Soils: Problems and Practice in Foundation and Pavement Engineering, John Wiley and Sons, Inc. New York.*
6. *Manohara Reddy R, Dargakumar N and Mallikarjuna Rao K (1999):"Beneficial use of fly ash for sub-base courses" Proceedings of the national seminar on fly ash characterization and geotechnical applications. IISc, Bangalore, 55-59.*

7. *Mitchell, J. K. (1976). Fundamentals of soil behaviour, John Wiley and Sons, Inc. New York.*

8. *NarasihmaRao, A.V., and Ramesh, P. 1999, Effect of Sodium Chloride on Plasticity, Swelling and Strength Chararacteristics of a Black Cotton Soil, Proceedings of Indian Geotechnical Conference, IGC-1999, Vol.2, pp.II-5 – II-8.*

9. *Ola, S.A. 1978, "Geotechnical properties and Behaviour of some Stabilized NigerianLateriticSoils," Quarterly Journal of Engineering Geology, London, U.K, Vol.11, pp. 145-160.*

10. *OSULA D.O.A "A comparative evaluation of cement and lime modification of laterite" March 1996 Engineering Geology, PP 71-81*

11. *Rogers, C.D.F. and Glendinning, S. 1993. "Modification of clay soils using lime", Proceeding of the Seminarheldat Loughborough University on Lime Stabilization (pp. 99-114). London: Thomas Telford*

12. *Sherwood P(1993) Soilstabilization with cement and lime. State of the Art Review, London: Transport Research Laboratory, HMSO.*

13. *Sridharan, A. and Sivapullaiah, P. V.2005.Mini compaction test apparatus for fine grainedsoils, Geotechnical TestingJl, ASTM Intl, Vol. 28(3), 1-20.*