INFLUENCE OF COMPACTIVE EFFORTS AND BAGASSE ASH ON LIME MODIFIED LATERITE

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Abstract

The effect of three compactive efforts (British Standard Light, BSL, West African Standard, WAS and British Standard Heavy, BSH) and bagasse ash (an agro-industrial waste from sugar mills) admixture on lime modified laterite are presented. The laterite, classified as A-7-6 using AASHTO soil classification, collected from Shika area of Zaria, was modified with a maximum of 4 % lime and 8 % bagasse ash, by dry weight of the soil. Test results showed increase in the particle sizes with higher dosages of the additives; the particle sizes decreased with higher compaction energy. There was decrease in maximum dry density (MDD) with higher dosages of the additives and compaction energy. Optimum moisture content (OMC) increased with higher concentrations of additives but decreased with higher compactive effort. There was also improvement in the shear strength parameters with higher dosages of additives and compaction energy. The results show that the soil modified with an optimum of 1% lime and 6% bagasse ash admixture meets the Highway Research Board limits, Millard and O'Reilly freeflow criterion as well as the limits set by Nigerian General Specifications, at all the compaction energy levels considered.

INTRODUCTION

In the construction of stabilized soil roads, cost of construction can be reduced considerably by selecting locally available materials and soils. However, where locally available soil is very poor and cannot withstand the expected traffic axle loads, its properties can be improved through stabilization. In some areas, locally occurring soils and soil aggregate combinations are of very good quality and require least processing such as compaction to achieve the desire properties. In other places, naturally occurring soils may require modification with suitable materials.

Laterite, which is in abundance in tropical regions of the world, including Nigeria, is used extensively, as base and sub-base road materials for low cost roads and those that carry low to medium traffic. Laterite may be classified as problem and non-problem types. Problem laterites are those that have reputation of being problematic in road construction. Pavement swelling, depression and lateral movements in the presence of water even under moderate wheel loads are negative effects associated with the used of such problem laterites. They are characterized by high natural water contents and liquid limits, low natural densities and friable and/or crumble structure (Obeahon, 1993).

In order to improve the engineering properties of problem soils, geotechnical engineers have been conducting research aimed at stabilizing deficient soils by employing low cost stabilizing additives such as by-products of industrial manufacturing processes and recently agricultural by-products, that might pose a nuisance to the environment. Stabilization is the treatment of soils to enable their strength and durability to be improved such that they become suitable for construction (Rosenak, 1963; Gilliot, 1968; Singh and Singh, 1991; Heath, 1992). Ordinary Portland cement and lime are the known conventional additives used in soil stabilization. The use of waste by-products emanates from the need to economically reduce the quantities of Portland cement and lime required to stabilize soil. In soil-lime stabilization, addition of lime below the lime stabilization point is termed soil-lime modification (Singh and Singh, 1991). This increase the workability of the soil, that is, produces an immediate increase in the plastic limit while lowering the moisture content (Barnes, 2000).

Osula (1991) reported modification of problem laterite using lime in order to change the physical properties of the soil and to make it suitable for use or act as an admixture for cement stabilization. This process is different from soil stabilization, which is aimed at improving strength properties of the soil. The evaluation was based on the limits set by Nigerian General Specifications (1997) for materials that can be used directly in pavement construction. The limits are as follows: liquid limit and plasticity index less than 30 and 12 % respectively, A-2-6 as AASHTO classification and percent passing BS No 200 sieve of 25 and 35 % for sub-base and base materials, respectively.

When lime is added to clay soils, calcium ions are combined initially with or adsorbed by clay minerals which lead to improvement in soil workability, increase in the plastic limit and a decrease in liquid limit. The optimum lime required for maximum increase of the plastic limit value of a soil is referred to as the lime fixation point (Singh and Singh, 1991). Lime added in excess of the fixation point is utilized in the cementation process and gives rise to an increase in soil strength. The increase in strength has been attributed to the formation of poorly ordered reaction products that surround the clay minerals (Gilliot, 1968). Generally, the amount of lime needed to modify a clay soil varies from 1 to 4 % (Nelson and Miller, 1992; Yoder and Witczak, 1975).

Bagasse is the by-product obtained after crushing and extracting sugar from sugarcane. According to Misari et al. (1998), Nigeria produces about 1 million metric tonnes of sugarcane and has the potential of producing about 11.76 millions metric tonnes. Bagasse constitutes about 30 % by weight of sugarcane and has ash yielding value of about 2.48 % (Ogbonyomi; 1998). The ash is reported to be a good source of pozzolana because of its richness in silica that is substantially in the amorphous form that reacts with lime (TRL, 1993). The unburnt bagasse has also been used for stabilizing soil (Eko and Riskowki, 2001; Osinubi and Stephen, 2005, 2007; Osinubi et al. 2007a,b; 2008a,b). This study is aimed at assessing the influence of compactive efforts and bagasse ash admixture on lime modified laterite.

LOCATION AND GEOLOGY OF STUDY AREA

The soil sample used for this study was collected from Shika area of Zaria (Longitude 7^0 36'E, Latitude 11^0 4'N) by method of disturbed sampling during the dry season. A study of the geological map of Nigeria (Areola, 1982) and the soil map of Nigeria (Akintola, 1982) reveals that the soil sample belongs to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks. Osinubi (1998) reported the predominant clay mineral to be kaolinite.

METHODS OF TESTING

Index Properties

Samples were collected at a depth of between 1.5 m and 2.5 m corresponding to the B - horizon usually characterized by accumulation of materials leached from the overlying A- horizon. Preliminary classification tests as well as tests to determine compaction characteristics and shear strength parameters (c and) were performed on the natural soil and on the soil-lime-bagasse ash mixes in accordance with B.S 1377 (1990) and Highway Manual (1972). Samples used for particle size distribution were prepared at the mixtures' various optimum moisture contents and allowed to dry before carrying out the test.

Sourcing and Ashing of Bagasse

The bagasse used for this study was locally sourced, sorted to remove unwanted materials. It was openly burnt to ash at temperatures between 500 and 700 ^{0}C. Before usage, the ash was sieved to remove the unashed char and was ground and passed through sieve No. 200 with 75 m aperture. The oxide composition was determined using X-ray fluorescent analysis

RESULTS AND DISCUSSION

Index Properties

The index properties of the natural soil are summarized in Table 1. Fig. 1 shows the particle size distribution. Based on the requirement of the Nigeria General Specifications (1997), the soil is adjudged unsuitable for direct use as base or sub-base material. On the basis of the Highway Research Board (1943) and O'Reilly (1965) free-flow criterion, this laterite is adjudged unsuitable for direct stabilization.

Table 1: Properties of the natural soil

Property	Quantity
Natural Moisture Content (%)	6.55
Percent Passing BS No. 200 Sieve	63
Liquid Limit (%)	41
Plastic Limit (%)	18
Plasticity Index (%)	23
Group Index	12
AASHTO Classification	A-7-6
Maximum Dry Density (Mg/m^3)	
British Standard Light	1.84
West African Standard	1.91
British Standard Heavy	1.99
Optimum Moisture Content (%)	
British Standard Light	15
West African Standard	12
British Standard Heavy	11
Cohesion (kN/m^2)	
British Standard Light	140
West African Standard	230
British Standard Heavy	245
Angle of internal friction (degrees)	
British Standard Light	18
West African Standard	19
British Standard Heavy	20
Specific Gravity	2.69
Organic matter content (%)	6.75
Color	Reddish brown

Bagasse Ash

The oxide composition of bagasse ash is summarized in Table 2. The combined percent composition of SiO_2, Al_2O_3 and Fe_2O_3 is 70.14, which is more than the minimum value of 70 % specified by ASTM C618 (1978) as indicative of pozzolanic activity. The specific gravity of the bagasse ash is 2.22.

Table 2: Oxide composition of bagasse ash

Oxide	SiO_2	Al_2O_3	Fe_2O_3	K_2O	MgO	CaO	Loss on ignition
Concentration (%by weight)	57.95	8.23	3.96	2.41	1.17	4.52	5.00

Effect of Compactive Efforts on the Particle Size Distribution of Soil-Lime-Bagasse ash Mixtures

Typical particle size distribution curves for soil-lime-bagasse ash mixed at the OMC for the BSL, WAS and BSH energy levels are shown in Figs. 2 - 4. At specific lime contents, reduction in the percentage of fines and complete transformation of clay fraction with bagasse ash content were noticed at BSL compaction energy level. This could be attributed to the higher OMC value that is associated with this energy level. The bagasse ash content caused the soil-lime-bagasse ash mixture to flocculate and agglomerate more and hence the soil-lime-bagasse ash mixture became coarser and thus enabled the clay fraction to form larger soil sizes. The reduction in the

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Similar trends was observed with the WAS and BSH compaction energy levels. The percent passing BS No 200 sieve increased with higher energy level from BSL to BSH. This could be attributed to the decreased OMC associated with the energy levels, which hitherto determined the water available for the pozzolanic reactions. The decrease in the particle sizes with increase in compaction energy can also be attributed to breakage of the formed larger particles, thus resulting to smaller particles. The results indicate that the treated soil, meet the Nigerian General Specification requirements of not more than 25 % and 35 % passing BS No 200 sieve for sub-base and base materials respectively.

Effect of Compactive Efforts on the Compaction Characteristics of Soil-Lime-Bagasse ash Mixtures

The variations of MDD and OMC with bagasse ash admixed with specific percentages of lime are presented in Figs. 5 and 6, respectively, for the three compactive efforts. Generally, MDD increased with higher compaction energy in the order BSL-WAS-BSH compaction and decreased in OMC in the same order. This trend is in agreement with Osinubi (1998) who studied the influence of BSL and WAS compaction efforts on the compaction and strength characteristics of lateritic soil treated with lime. Each of the compaction energy considered, there was generally a decrease in MDD and increase in OMC with lime/bagasse ash content in agreement with Lees et al. (1982), Ola (1983), Osula (1991) and Obeahon (1993). The initial decrease in MDD with bagasse ash content agrees with Nicholson and Kashyap (1993) as well as Chu and Kao (1993) who reported that it might be attributed to the comparatively low specific gravity of the bagasse ash and the enhancement of the flocculation and agglomeration of clay particles. The increase in MDD at 4 % bagasse ash content up to 6 % bagasse ash content could be due to the explanation advanced by Brandl (1980) and Osinubi and Katte (1997) that molecular rearrangement in the formation of "transitional compounds" which had higher densities at 6 % bagasse ash content after which a decline in MDD with increase in bagasse ash was observed. This trend was observed at all the energy levels considered.

Comparison of the decrease trend of the MDD for the three compaction energy levels considered show that lower MDD losses were recorded at the BSH energy level. This could be as a result of the lower OMC and its change trend that was associated with these energy levels as well as the high compaction energy.

Effect of Compactive Efforts on the Shear Strength Parameters of Soil-Lime-Bagasse ash Mixtures

The variations of cohesion and angle of internal friction with bagasse ash content for the three compaction energy levels are shown in Figs. 7 and 8. Cohesion reduced with higher bagasse ash content because of the enhancement of the ion exchange reaction between lime and soil, which was further enriched with silica from the bagasse ash.

The angle of internal friction increased with higher bagasse ash content to peak values (e.g for WAS; 30, 31, 32 and 34°) at 6 % bagasse ash content for specific (1 %, 2 %, 3 % and 4 %) lime contents respectively. The observed increases were due to increases in particle sizes (see Figs. 2 - 4) and reduction in the clay fraction of the soil. The decrease in the angle of internal friction beyond 6 % bagasse ash content was due to excess bagasse ash that was not mobilized for reaction. This resulted in weak bonds between the newly formed larger particle sizes that were easily broken during compaction. The decrease in MDD beyond 6 % bagasse ash content (see Fig. 5) supports the above explanation. This is because as the low specific gravity bagasse ash occupied the spaces between the transitional compounds formed, it reduces the frictional resistance between the formed compounds.

The trends of variations in the cohesion and angle of internal friction with bagasse ash contents are similar for the three compaction energy levels considered. The higher values of cohesion and angle of internal friction recorded at the WAS and BSH compaction levels were due to the relatively higher compactive efforts that increased the bonding between the particle sizes.

In summary, the study recorded a shift of particle size distribution curves from the region of fine-grained soil to the region of coarse-grained soil at particular compactive efforts. Comparison of the three compactive efforts shows a decrease in the particle sizes with increase in compactive effort which conforms with earlier findings by Osinubi and Katte (1997). Variation of both MDD and OMC at particular compactive efforts agree with findings by Ola (1983), Osula (1991), Obeahon (1993), Osinubi and Katte (1997) as well as Osinubi (1998).. The trends of MDD and OMC with increased compactive effort conform with Osinubi and Katte (1997). Improvement of both cohesion and angle of internal friction with increase in lime/bagasse ash content and compactive effort agrees with findings reported by Osinubi (1995).

CONCLUSION

From the results obtained in this study, the following conclusions can be drawn:

1. The laterite was identified to be an A-7-6 soil based on AASHTO classification system.
2. Generally, soil particle sizes decreased with higher compactive efforts from BSL to BSH. The soil particle sizes increased with higher

bagasse ash content at the compaction energy levels considered. .

3. The optimum moisture content (OMC) and maximum dry density (MDD) decreased and increased, respectively, with higher compactive effort for the soil-lime-bagasse ash mixtures. There was a general decrease in MDD with bagasse ash content for the compactive efforts considered.
4. The treated soils met the requirements set by the Nigerian General Specification (1997) at the compactive efforts considered.
5. The Highway Research Board (1943) limits as well as the Millard and O'Reilly (1965) free-flow criterion were satisfied at compaction energies considered.
6. Treatment of A-7-6 lateritic soil with a mixture of 1 % lime and 6 % bagasse ash admixture will require less compactive effort to achieve the desired soil characteristics.

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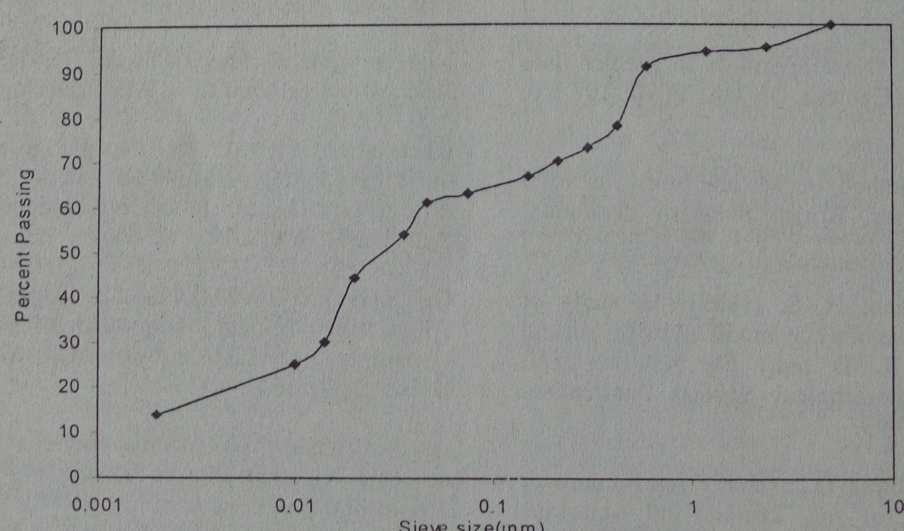
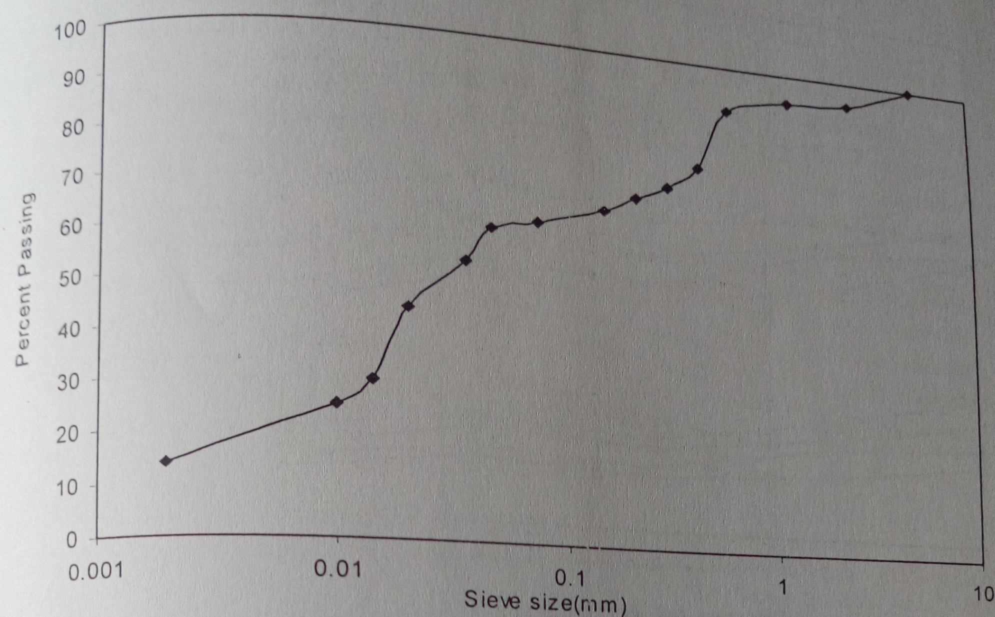


Fig. 1 Particle size distribution curve of the natural soil



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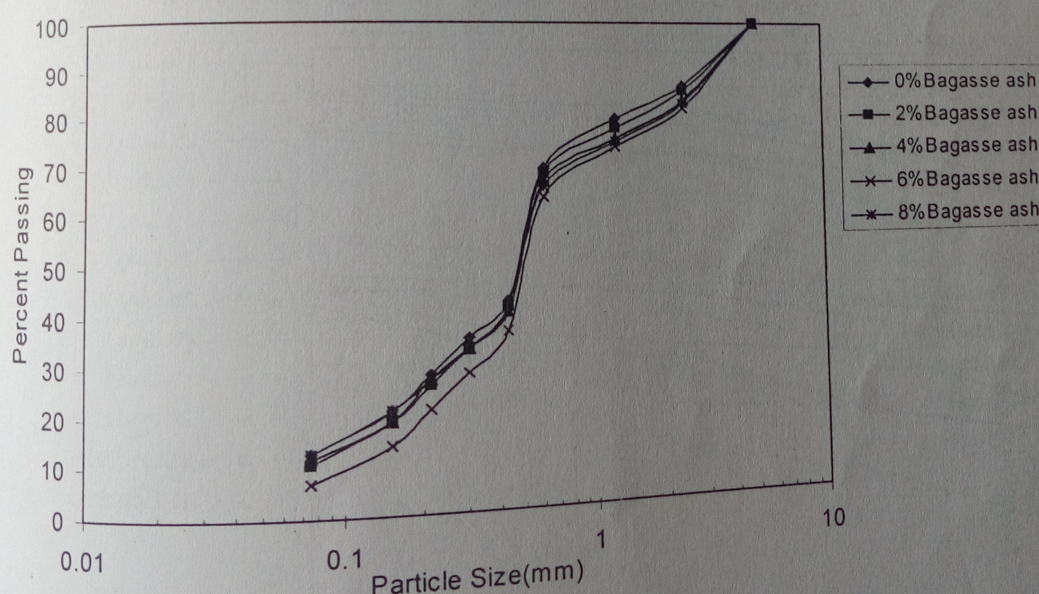

Fig. 4 Particle size distribution curves of soil treated with 1 % lime/Bagasse ash mixed at OMC for BSH compaction

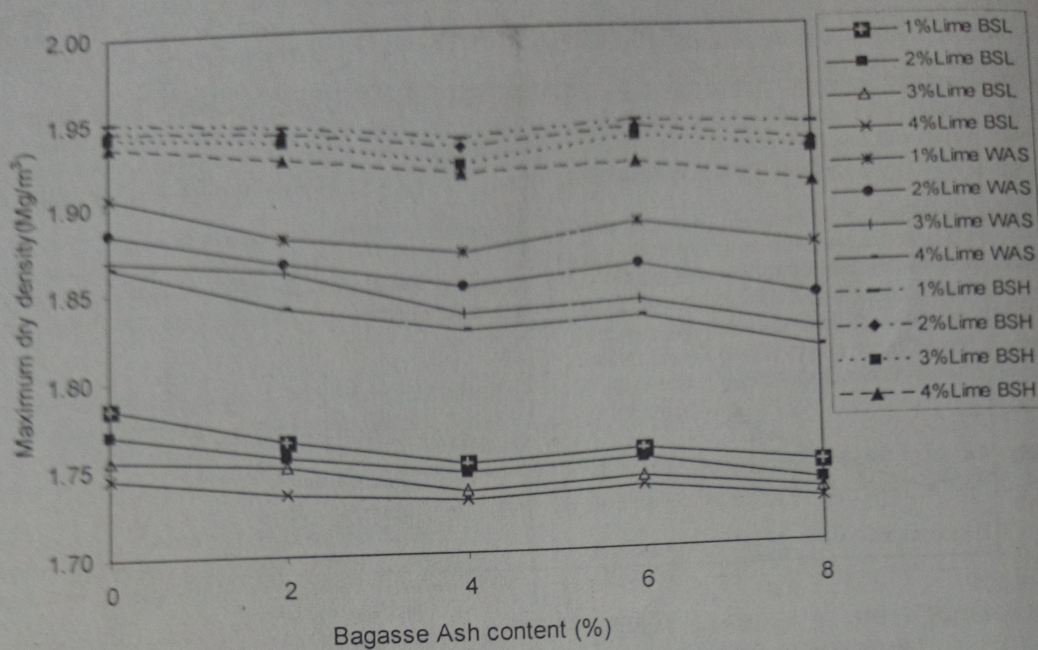

Fig. 5 Variation of maximum dry densities with bagasse ash content for the different compactive efforts

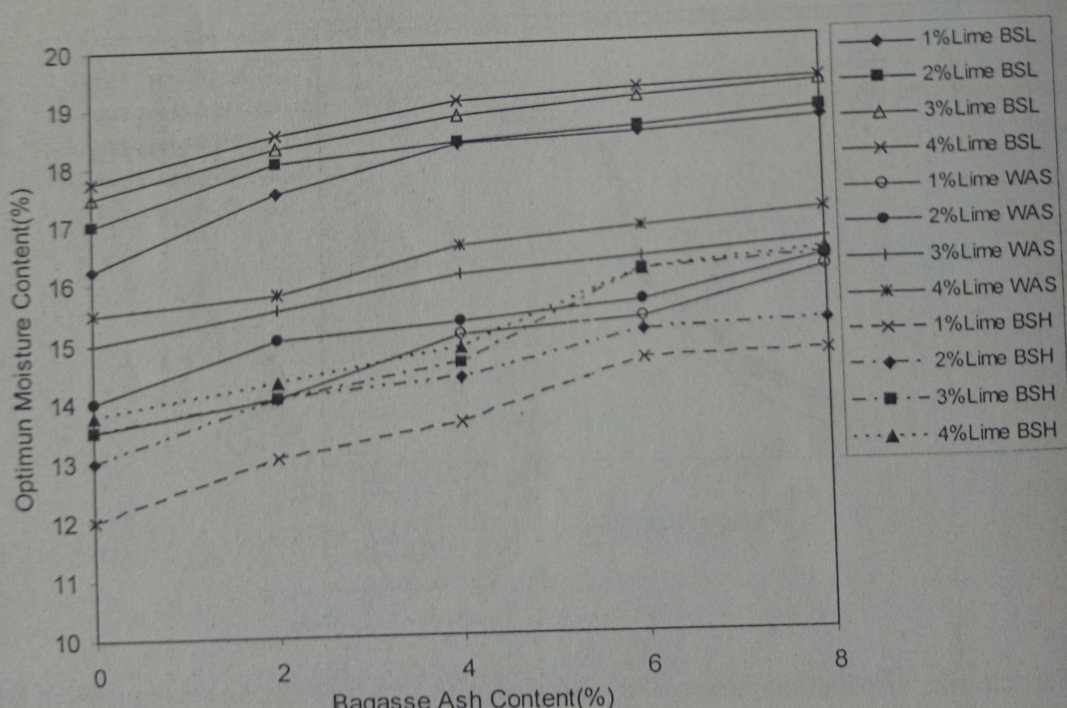

Fig. 6 Variation of Optimum moisture contents with bagasse ash content for the different compactive efforts

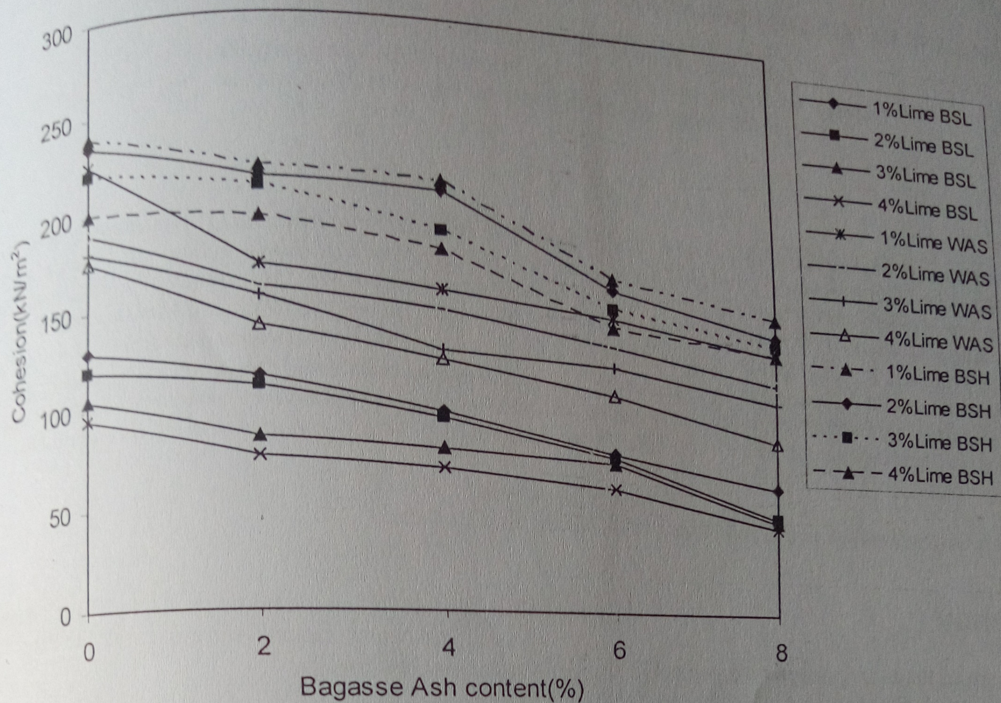

Fig. 7 Variation of cohesion with bagasse ash content for the different compactive efforts

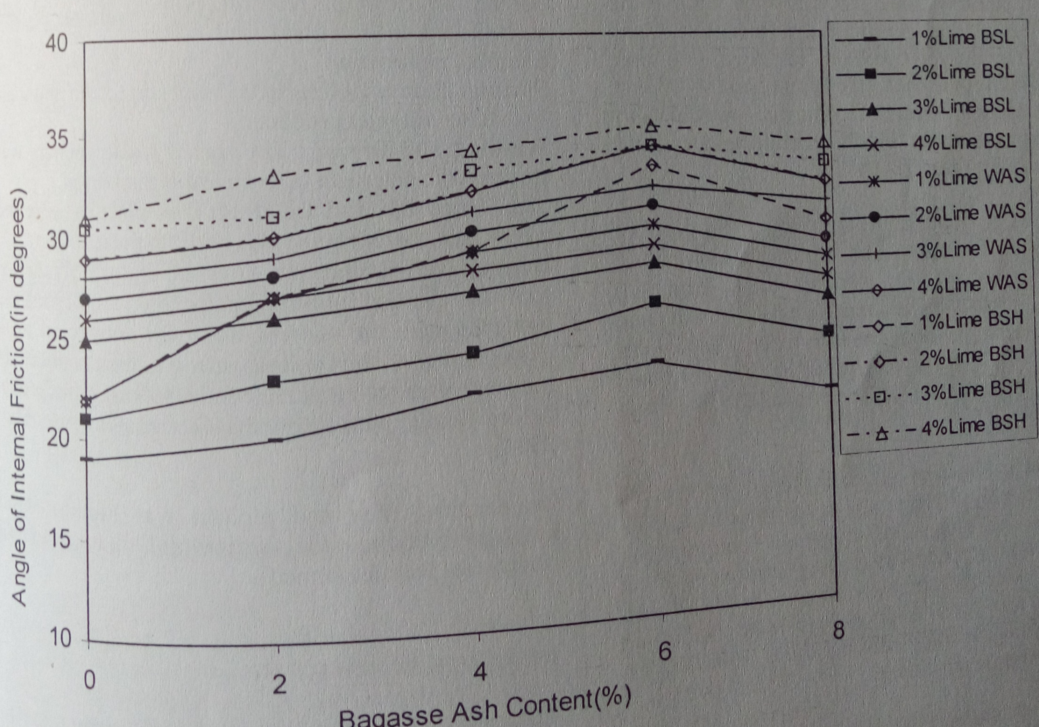

Fig. 8 Variation of angle of internal friction with bagasse ash content for the different compactive efforts