USE OF LIME AND BAGASSE ASH IN THE MODIFICATION OF LATERITE

Osinubi, K. J[1] and Alhassan, M[2] (corresponding author)

[1] Department of Civil Engineering, A. B. U. Zaria.

[2] Department of Civil Engineering Federal University of Technology, P M B 65, Minna.

E-mail: alhassankuta@yahoo.com

Abstract

Laterite classified as A-7-6 using AASHTO soil classification, was collected from Shika area of Zaria and modified with up to 4 % lime content by dry weight of soil. Effect of bagasse ash on the modified soil was studied with respect to particle size distribution, plasticity characteristics, compaction characteristics and shear strength parameters, using British Standard Light (BSL) compaction energy. Results obtained indicate increase in the particle sizes (i.e., curves shifted from the region of fine-grained soil to coarse-grained soil). Improvement in the plasticity of the soil was recorded with decrease in liquid limit and increase in plastic limit. The maximum dry density (MDD) generally decreased when treated with 1 % lime/6 % bagasse ash from 1.79 to 1.76 Mg/m^3, while the optimum moisture content (OMC) increased from 16.25 to 18.40 %. The shear strength parameters also generally improved with a decrease in cohesion from 130 to 80 kN/m^2, while angle of internal friction increased from 19 to 23^o at 1 % lime/6 % bagasse ash contents. On the bases of the compaction and shear strength parameters results, 6 % bagasse ash content can be admixed with 1 % lime for optimal laterite modification.

INTRODUCTION

Laterite is abundantly found in tropical regions of the world, including Nigeria, where they are used extensively, as base and sub-base road materials for low cost road and those that carry low to medium traffic. According to Gidigasu (1976),"soil group formed under weathering systems productive of the process of laterization, whose important characteristics is decomposition of ferro-alumino silicate minerals and the permanent deposition of sesquioxides (Al_2O_3 and Fe_2O_3) within the profile to form horizon of material. This material is known to the engineer and builder as laterite. In the process, silica is leached (washed) out". Laterites are nearly void of bases and primary silicates. They are neither hard nor capable of hardening on exposure to wetting and drying

Laterite may be classified as problem and non-problem types. Problem laterites are those that have reputation of being problematic in road construction. These types of soils are easily noticed in highway and airfield pavements where they are uses as sub-bases material, resulting in pavement swelling, depression and lateral movements in the presence of water even under moderate wheel loads. These types of laterite are characterized by high natural water contents and liquid limits, low natural densities and friable and/or crumble structure (Obeahon, 1993). Hence, it can be stated that laterites that do not possess these properties are non-problem types.

To improve the engineering properties of problem soils economically Nicholson (1993) Chu and Kao (1993) Eko and Riskowski (2001) recommended the use of low cost stabilizing additives such as by-products of industrial manufacturing processes and recently agricultural by-products, that might cause a nuisance to the environment. Stabilization is the treatment of soils to enable their strength and durability to be improved and made suitable for road construction, beyond their classification (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 for stabilization. In soil-lime stabilization, addition of lime within the lime fixation point is termed soil-lime modification (Singh and Singh, 1991). Lancaster-Jones et al. (1981) reported that as lime reacts with the clay, or additives such as fly-ash (or bagasse ash), it causes hardening due to the formation of calcium silicates. This produces an immediate increase in the plastic limit while lowering the moisture content (Barnes, 2000).

Generally, the amount of lime needed to modify a clay soil varies from 1 to 4% (Yoder and Witczak, 1975; Nelson and Miller, 1992). When lime is added to clay soils, calcium ions are combined initially with or adsorbed by clay minerals which leads to an improvement in soil workability; that is, increase in the plastic limit of the clay and generally to a decrease in its liquid limit. The optimum lime additive for maximum increase of the plastic limit of the 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). Silica rich ash (e.g. Bagasse ash) further promotes the reaction of lime admixtures, especially in soils of deficient pozzolans, that is soil with less silicon, iron and alminium oxides (Nicholson, 1993).

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 million 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 contained in amorphous form (TRL, 1993) that reacts with lime. The unburnt bagasse has also been used for stabilizing soil (Eko and Riskowki, 2001). This is in line with the United Nations Organization, in the consideration of employing stabilized soil, especially from locally available materials for the building of houses and roads at low cost, in developing regions of the world (Gilliot, 1968). In conformity with this, geotechnical engineers have recently utilized locally available agricultural by-products such as rice husk ash (Alimi, 1989) and sugarcane bagasse ash (Osinubi and Stephen, 2005, 2007; Osinubi and Alhaji, 2005; Osinubi et al., 2007a,b;2008a,b) for stabilization. This attempt is aimed at reducing the use of industrially manufactured soil stabilizing agents such as cement, lime and bitumen which are usually costly. The aim of the study is to evaluate the effect of bagasse ash on lime modified laterite.

GEOLOGY AND LOCATION OF STUDY AREA

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

METHODS OF TESTING

Index Properties

Samples were collected at a depth of between 1.5 and 2.5 m corresponding to the B- horizon usually characterized by accumulation of materials leached from the overlying A- horizon. Classification tests as well as tests to determine compaction characteristics and shear strength parameters (c and) were performed on the natural soil in accordance with BS 1377 (1990).

Sourcing and Ashing of Bagasse

The bagasse used for this study was locally sourced and ashed because of the non-availability of the material in the major sugar mills in the country. The bagasse, from which unwanted materials were removed, was openly burnt to ash within a temperature range from 500 to 700 °C determined using a thermocouple. The chemical composition of the resulting ash was determined using flame photometer and the atomic absorption spectrophotometer (AAS). Before use the ash was sieved to remove the unashed char and then pulverized and passed through the 75 m sieve size.

DISCUSSION OF RESULTS

Index Properties

The results of the preliminary tests carried out on the natural soil are summarized in Table 1. The particle size distribution of the natural soil is shown in Fig. 1. The clay mineralogy of soil from the study borrow pit which was determined by X-ray diffraction analysis was reported by Osinubi and Katte (1997) as well as Osinubi (1998a) to be predominantly kaolinite mixed with quartz.

Table 1: Index 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
AASHTO Classification	A-7-6
Group Index	12
Maximum Dry Density, Mg/m^3	1.84
Optimum Moisture Content, %	15
Cohesion, kN/m^2	140
Angle of Internal Friction, Degrees	18
Specific Gravity	2.69
Organic matter content,%	6.75
Color	Reddish brown

Using the Nigeria General Specifications (1997) criteria, the soil is adjudged unsuitable for direct use as base or sub-base material. Also, on the basis of the Highway Research Board (1943) values less than 50 % passing BS No. 200 sieve, 40 % LL and 18 % PI as well as the Millard and O'Reilly (1965) free-flow criterion of the product of the PI and percent passing BS No. 36 (0.425 mm aperture) not greater than 1000 for assessing suitability for stabilization, this laterite was adjudged unsuitable for direct stabilization.

Pozzolanic Activity of Bagasse Ash

The oxide composition of the ash is summarized in Table 2. The specific gravity of the ash was determined to be 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
Quantity (%)	57.95	8.23	3.96	2.41	1.17	4.52	5.00

The combined percent composition of SiO2, Al2O3 and Fe2O3 summarized in Table 2 is 70.14, which is more than the minimum value of 70 % specified by ASTM C618 (1978) as indicative of pozzolanic activity. However, the value obtained is less than that reported by Ogbonyomi (1998). The variation might be due to the sugarcane species used, the method of the bagasse sorting, the burning method and the ashing temperature.

Effect of Bagasse Ash on the Particle Size Distribution of Lime Modified Soil

The particle size distribution curves for the lime modified soils with no bagasse ash admixture is as shown in Fig. 1. A reduction in the percentage of fines with lime content was observed, in addition to shifts in the grading curves from the region of fines fraction to the region of granular soils. This agrees with results reported by Osula (1991) and Obeahon (1993).

The particle size distribution curves for soil modified with lime and bagasse ash admixture is as shown in Figs. 2 - 5. Addition of bagasse ash admixture to the soil lime mixture further reduced the percentage of fines. The bagasse ash caused the soil-lime mixture to further flocculate and agglomerate and consequently, the fines fraction bonded to form coarser soil fractions. That is, the silt sizes bonded to form pseudo-sand sizes, while the sand sizes formed larger sand sizes. This was enhanced by the formation of products of the pozzolanic reaction, taking place between the calcium hydroxide from lime and silica from both clay and the bagasse ash.

Effect of Bagasse Ash on the Plasticity Characteristics of Lime Modified Soil

The variations of the Atterberg limits with bagasse ash contents for soil-lime mixtures is as shown in Figs. 6 - 8. The liquid limit (LL) and plasticity index (PI) reduced with lime contents, while the plastic limit (PL) increased. These trends are consistent with those reported by Ola (1983), Obeahon (1993), Osinubi and Katte (1997) and Toro (1998). The reduction in LL with higher bagasse ash content lends more credence to the assertion of a reaction of an ion exchange reaction between lime and soil that was enriched by the pozzolanic bagasse ash (Nicholson, 1993).

The requirements of the Nigerian General Specifications (1997) for direct use of the materials in pavement construction were not met by all the soil lime bagasse ash mixtures due to their high LL values. However, the requirements of the Highway Research Board (1943) as well as the Millard and O'Reilly (1965) free flow criterion were satisfied.

Effect of Bagasse Ash on the Compaction Characteristics of Lime Modified Soil

The variation of maximum dry density (MDD) and optimum moisture content (OMC) of soil-lime mixtures with bagasse ash content is as shown in Figs 9 and 10, respectively. The initial decrease in MDD with bagasse ash content (see Fig. 9), which might be attributed to the comparatively low specific gravity of the bagasse ash and the enhancement of the flocculation and agglomeration of clay particles, is in agreement with Nicholson (1993) as well as Chu and Kao (1993). The increase in MDD observed at 6 % bagasse ash content could be due to the explanation advanced by Brandl (1980) and Osinubi and Katte (1997) that there was molecular rearrangement in the formation of "transitional compounds" which had higher densities at that dosage of bagasse ash. However, MDD decreased with further increase in bagasse ash content.

The increase in OMC with bagasse ash content was due to the larger quantity of water required for the pozzolanic reactions to take place (Chu and Kao, 1993; Nicholson, 1993; Osinubi and Katte, 1997). OMC decreased between 4 to 8 % bagasse ash content can be attributed to the formation of relatively stable compounds at this stage.

Effect of Bagasse Ash on the Shear Strength Parameters of Lime Modified Soil

The variation of cohesion and angle of internal friction of soil-lime mixtures with bagasse ash content is as shown in Figs. 11 and 12, respectively. The cohesion reduced while the angle of internal friction increased with bagasse ash content. The decrease in cohesion was due to the reduction in clay size fraction, due to ion exchange reaction between soil and lime that was enriched with silica from bagasse ash.

The angle of internal friction of the soil-lime mixtures increased with bagasse ash content up to 6 % ash content and then slightly decreased at 8 %. The initial increase was as a result of the increase in the particle sizes and reduction in the clay content of the soil (see Figs. 1- 5). The decrease in the angle of internal friction from 6 to 8 % bagasse ash content might be as a result of the excess bagasse ash that was not mobilized for the reaction. This resulted in weak bonds for the formation of the larger particle size that were easily broken during compaction. This can be further explained by the trend of the MDD, which decreased from 6 to 8 % bagasse ash content, arising from the occupation of the spaces between the transitional compounds, formed at 6 % ash content, by the bagasse ash which has a lower specific gravity. In summary, the study established the efficacy of bagasse ash as a pozzolana in agreement with Ogbonyomi (1998). The deficient soil treated with lime/bagasse ash was predominantly transformed from fine-grained to coarse-grained soil in agreement with Osinubi and Katte (1997.The workability of the soil improved on addition of lime/bagasse ash, This conforms with the reports of Ola (1983), Osula (1991), Nicholson (1993) and Toro (1998). Decrease in MDD with corresponding increase in OMC on addition of lime/bagasse ash agrees with Chu and Kao (1993), Nicholson (1993) as well as Osinubi and Katte (1997), while the trends of the shear strength parameters agrees with Osinubi (1995).

CONCLUSION

From the results of the investigation carried out in this study, the following conclusions can be drawn:

1. The laterite was classified as an A-7-6 (12) soil based on AASHTO classification system.

2. The particle sizes of soil modified with lime increased with higher bagasse ash content.

3. The liquid limit and plasticity index decreased, while plastic limit increased with higher lime content. This trend was further enhanced with increased bagasse ash content.

4. The optimum moisture content (OMC) of the soil-lime mixtures generally increased, while the maximum dry density (MDD) decreased with higher bagasse ash content. The trend of the MDD is in agreement with Osinubi and Katte (1997).

5. For soil-lime mixtures the cohesion decreased while the angle of internal friction increased with bagasse ash contents.

6. Based on the limits set by the Nigerian General Specifications (1997) of 30 % LL, 12 % PI, A-2-6 AASHTO classification and 25 % passing B.S No 200 sieve, the soil treated with lime and bagasse ash did not meet the requirements.

7. Based on Highway Research Board (1943) limits as well as Millard and O'Reilly (1965) free-flow criterion, the modified soil met the requirements at the ranges of bagasse ash considered.

8. Considering the effect of the bagasse ash on lime modified soil, it can be stated that A-7-6 laterite can be optimally modified with 1 % lime and 6 % bagasse ash content.

9. Bagasse ash enhanced soil-lime modification reaction and therefore lowered the quantity of the modifiers used.

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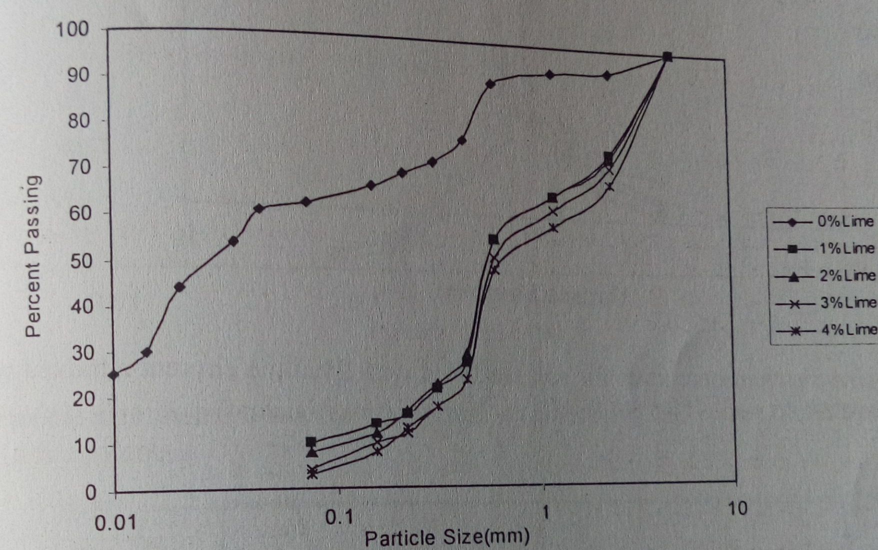

Fig. 1 Particle Size distribution curves for lime modified soil

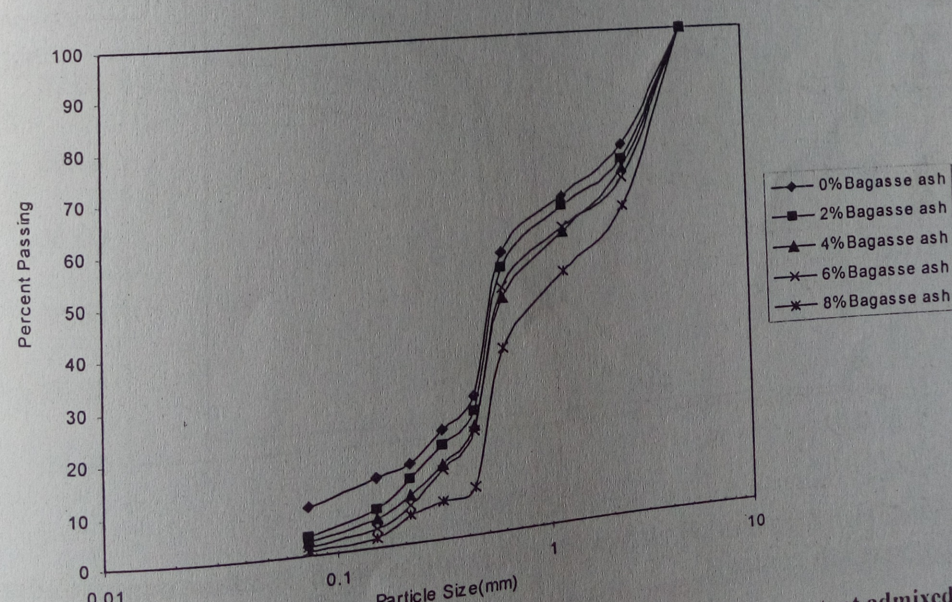

Fig. 2 Particle size distribution curves for soil modified with 1% lime content admixed with various bagasse ash contents

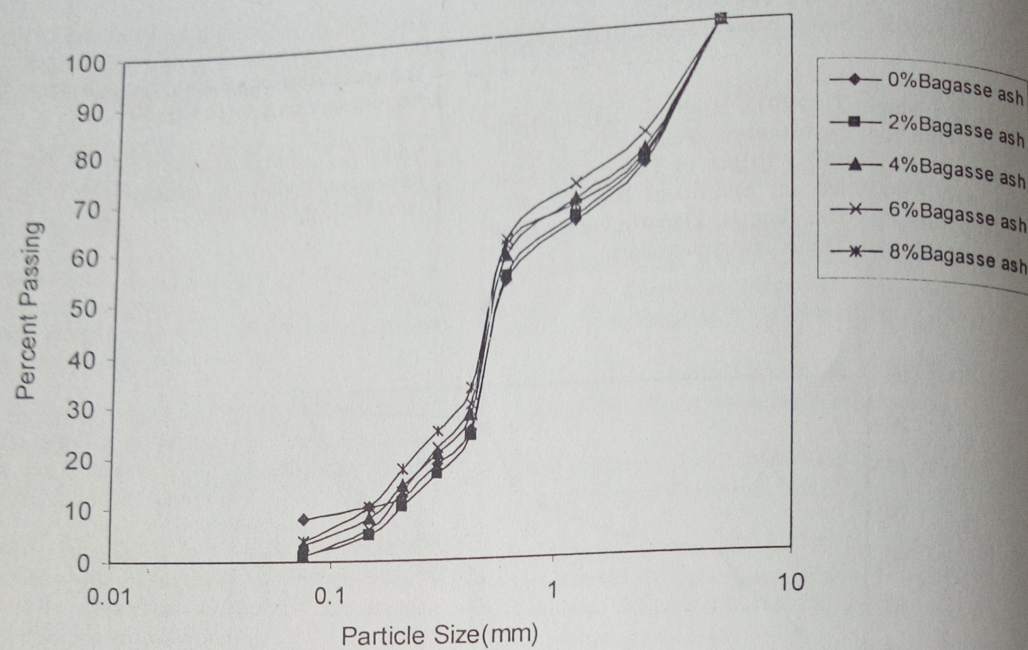

Fig. 3 Particle size distribution curves for soil modified with 2% lime content admixed with variou bagasse ash contents

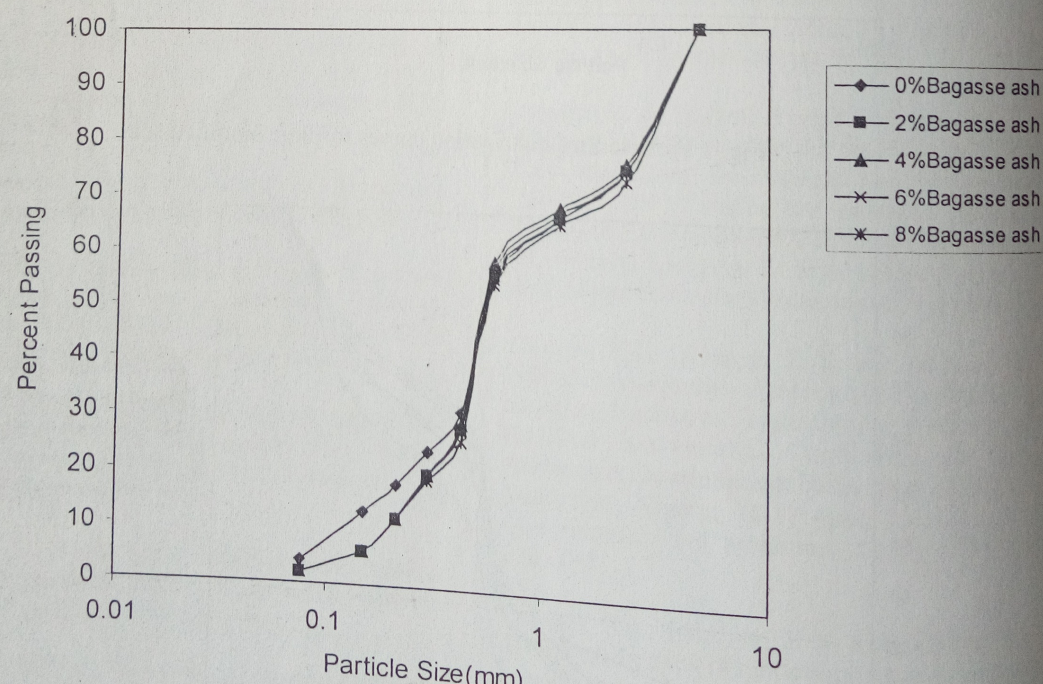

Fig. 4 Particle size distribution curves for soil modified with 3% lime content admixed with various bagasse ash contents

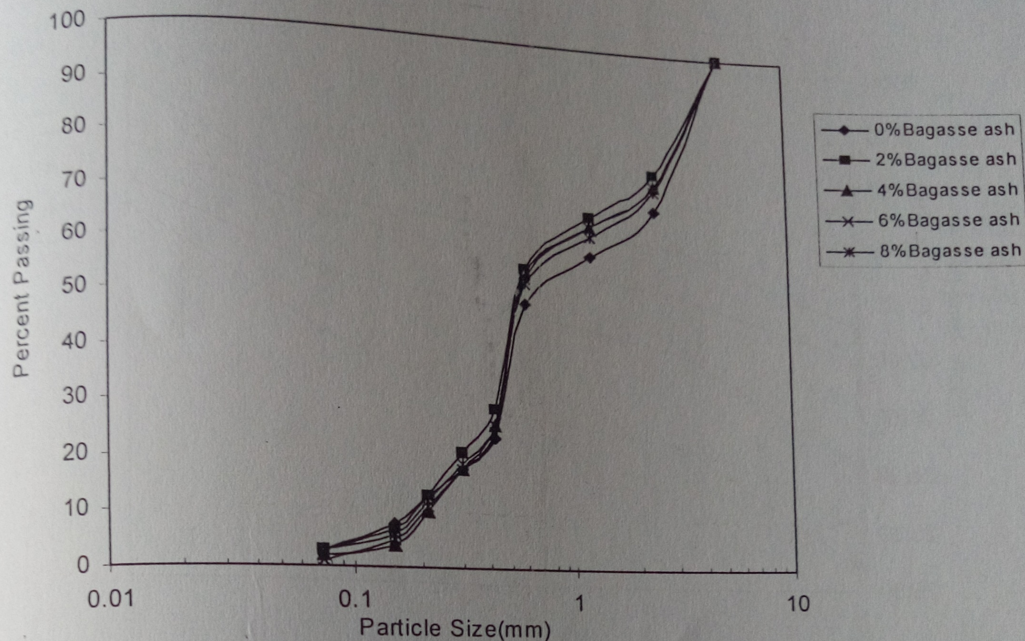

Fig. 5 Particle size distribution curves for soil modified with 4% lime content admixed with variou bagasse ash contents.

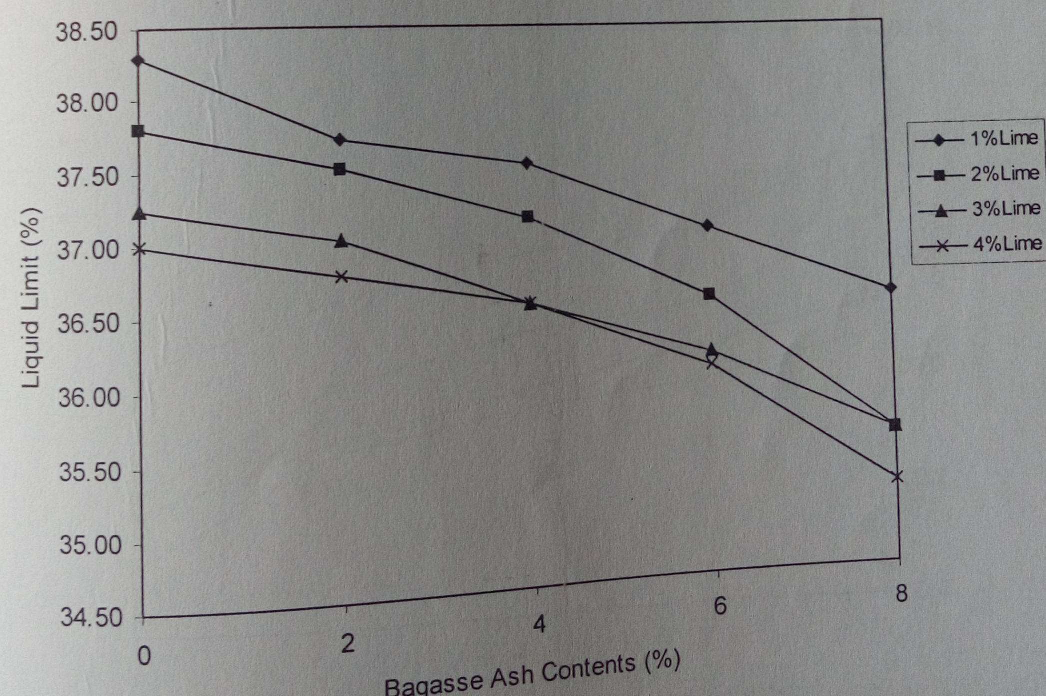

Fig. 6 Variation of liquid limit of soil-lime mixtures with bagasse ash content

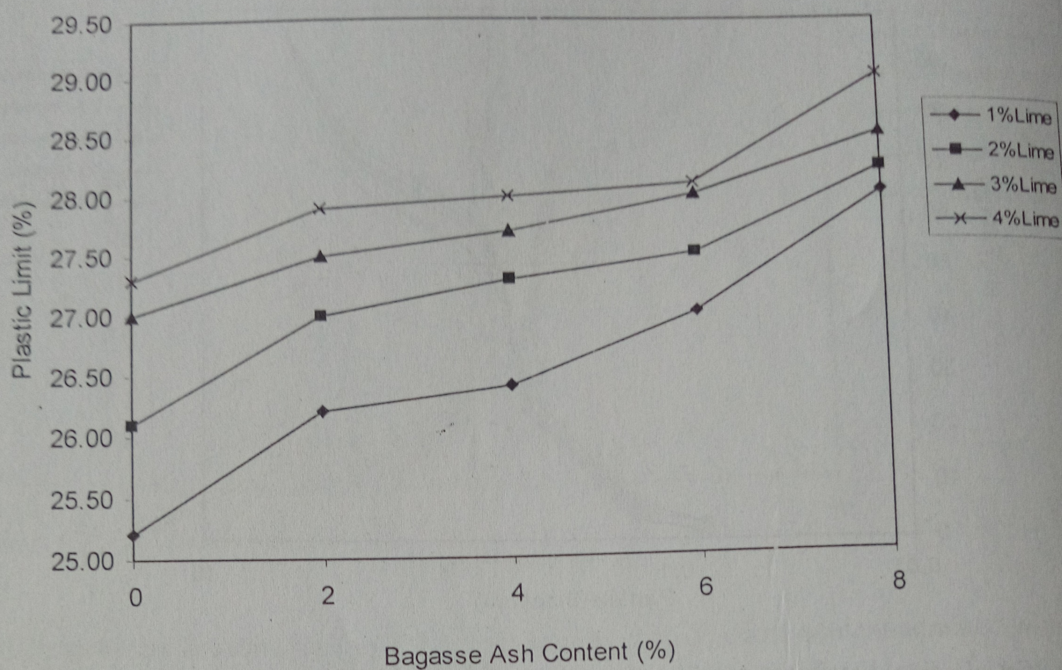

Fig. 7 Variation of plastic limit of soil-lime mixtures with bagasse ash content

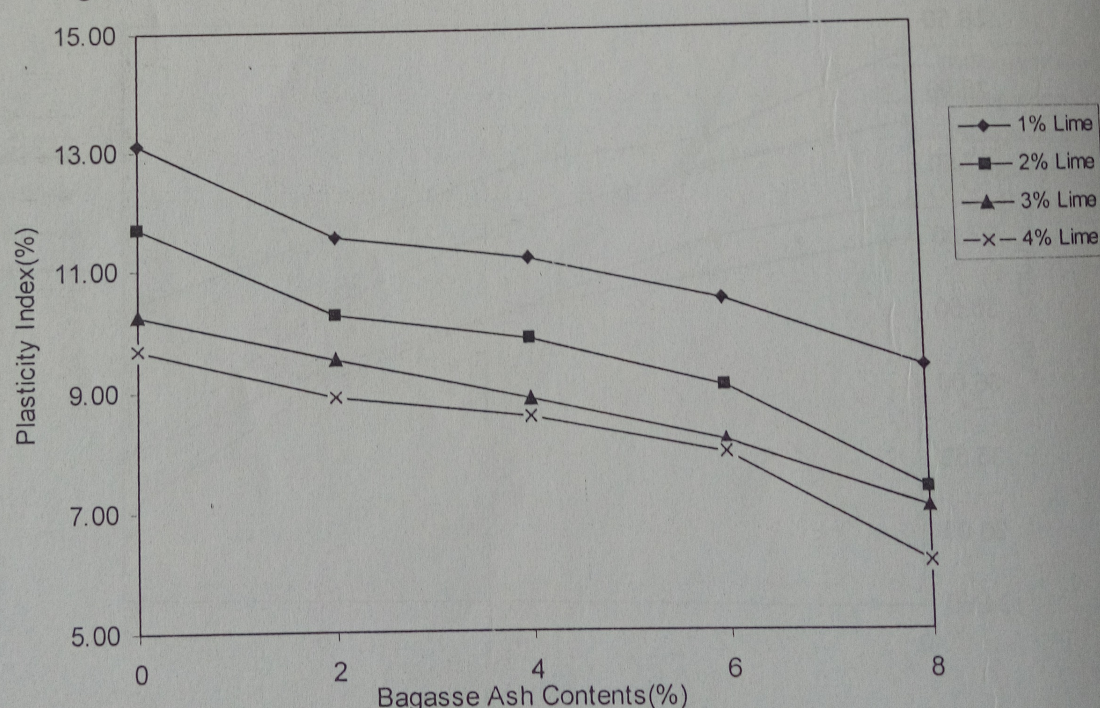

Fig. 8 Variation of plasticity index of soil-lime mixtures with bagasse ash contents

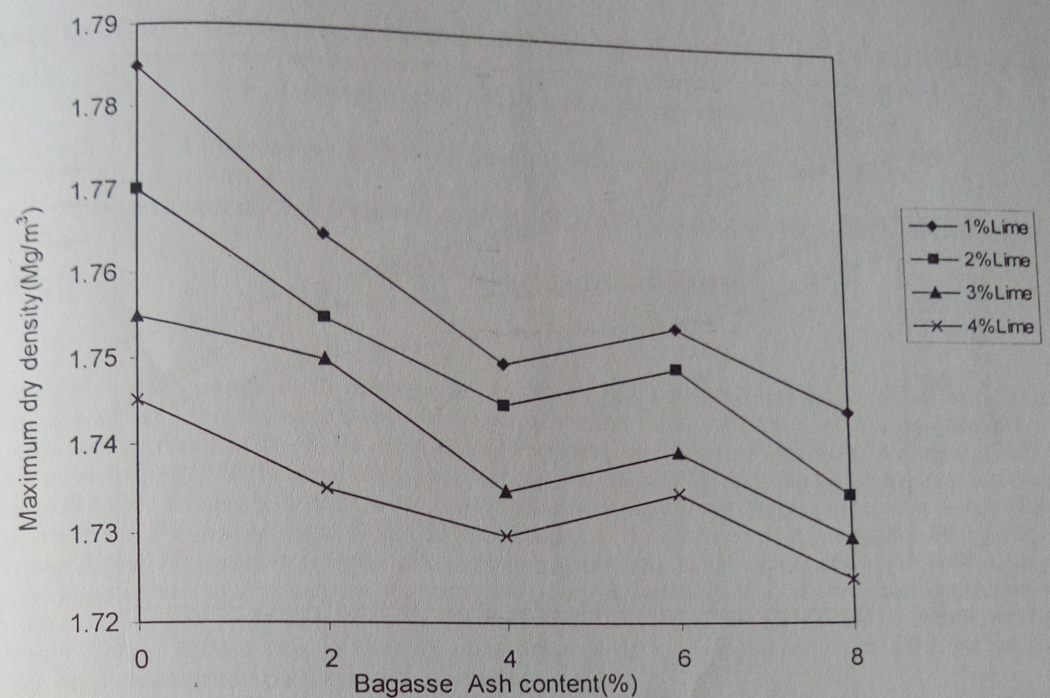

Fig. 9 Variation of maximum dry density of soil-lime mixtures with bagasse ash content

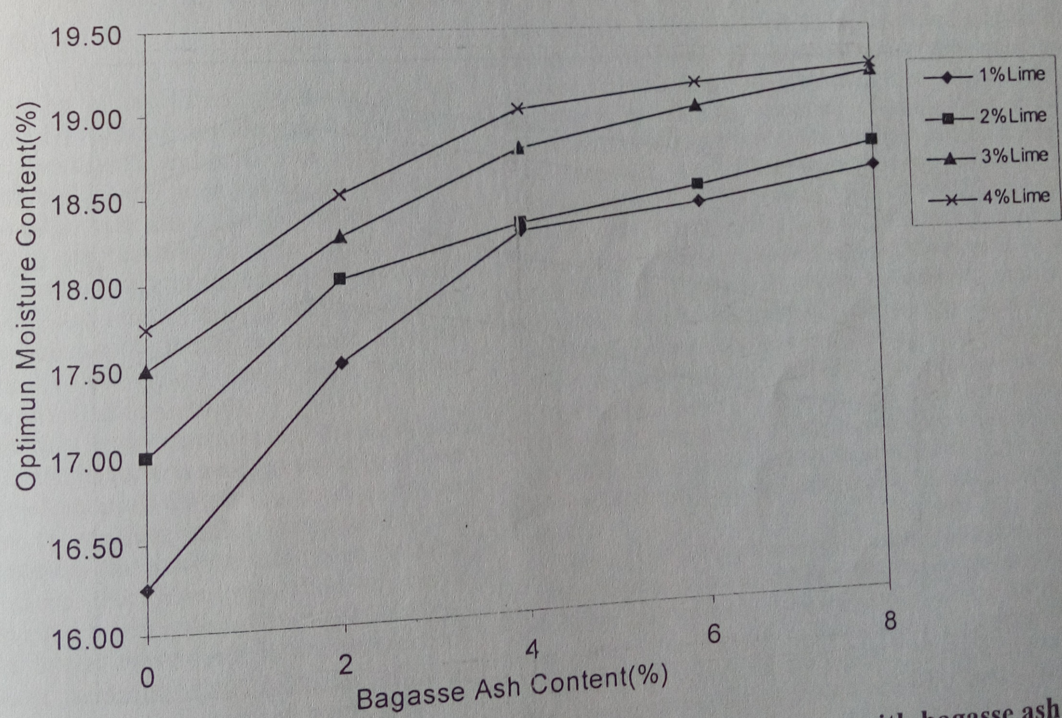

Fig. 10 Variation of optimum moisture of content of soil-lime mixtures with bagasse ash cont

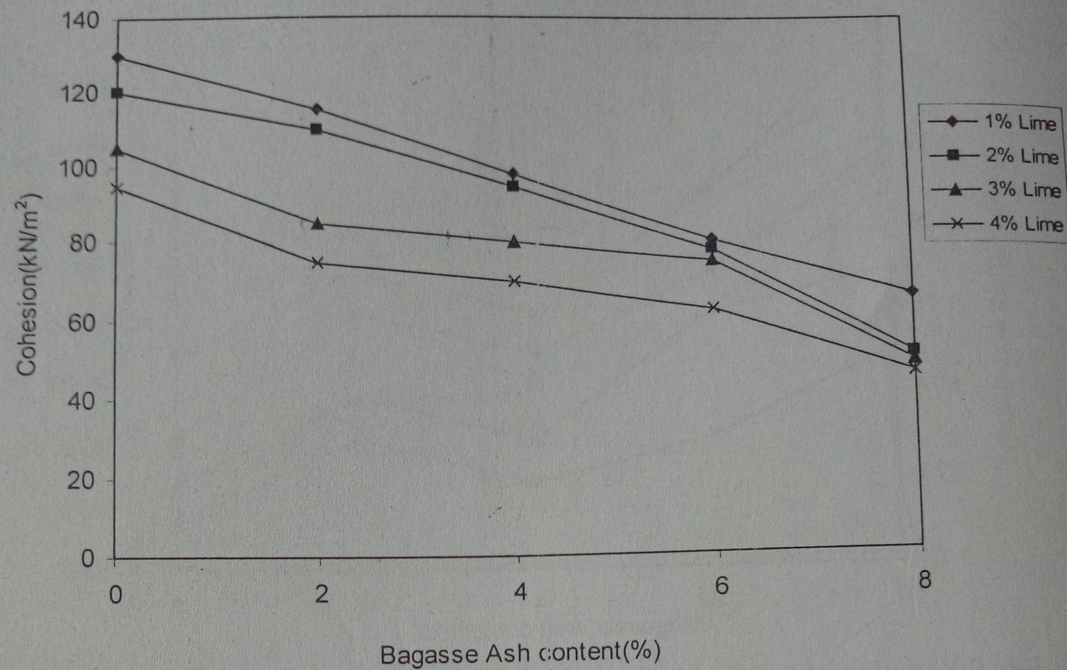

Fig. 11 Variation of cohesion of soil-lime mixtures with bagasse ash content

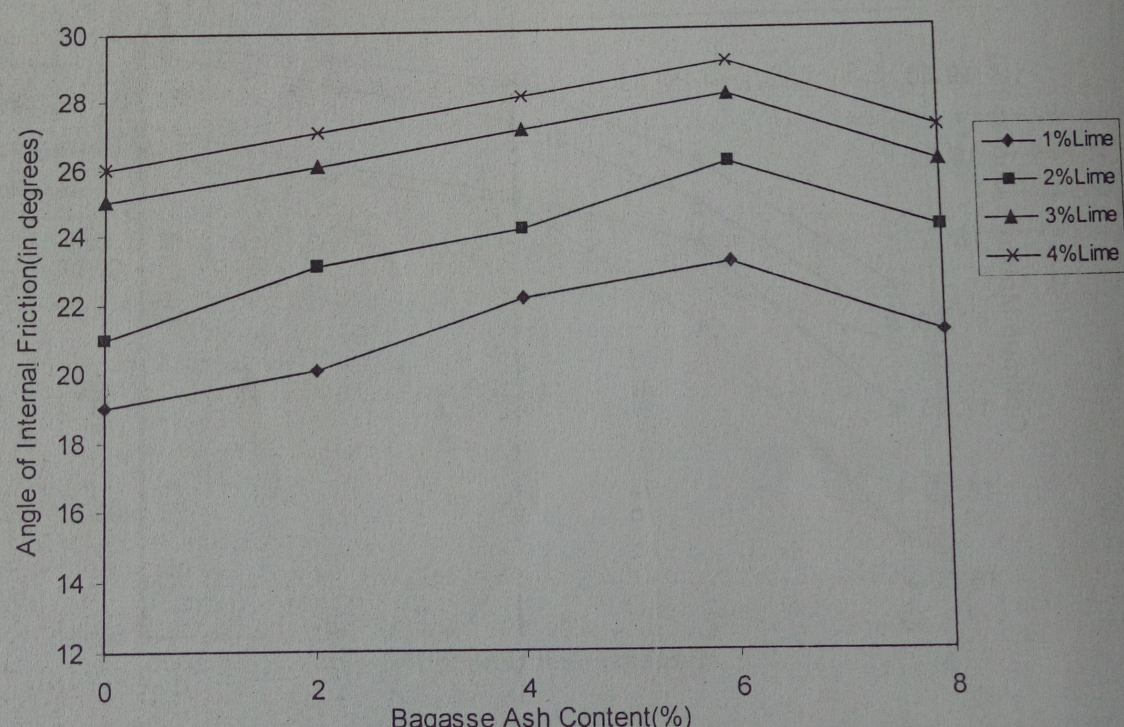

Fig. 12 Variation of angle of internal friction of soil-lime mixtures with bagasse ash content