STABILIZATION OF EXPANSIVE SOIL USING BAGASSE ASH & LIME

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ABSTRACT

The Expansive soil collected from Addis Ababa, Bole sub city, classified as an A-7-5 soil on the AASHTO classification was stabilized using 3% lime, 15% bagasse ash and 15% bagasse ash in combination with 3% lime by dry weight of the soil. The effect of the additives on the soil was investigated with respect to plastcity, compaction and California bearing ratio (CBR) tests.

The results obtained indicate an increase in optimum moisture content (OMC) and CBR value; and a decrease in maximum dry density (MDD) and plasticity of the soil for all additives. But there was also a tremendous improvement in the CBR value when the soil is stabilized with a combination of lime and bagasse ash. This shows a potential of using bagasse ash as admixture in lime stabilized expansive soil.

Keywords: Expansive soil, bagasse ash, lime, plasticity, compaction and strength characteristics.

INTRODUCTION

Expansive clays are known to exhibits dual characteristics of excessive swelling and shrinkage under different moisture conditions. This swelling-shrinkage characteristic of expansive soils which depends on the stress and suction history of the soil causes deformations which are significantly greater than elastic deformations and cannot be predicted by the classical elastic or plastic theory. The movement is usually in an uneven pattern and of such magnitude as to cause extensive damage to the structures and pavements resting on them [10].

In Ethiopia where these soils are found, the characteristic features of the soil behaviors which are majorly extensive cracks are obvious on road pavements and building structures. The cost implication of such defects and failures is very high.

Many ground improvement techniques have been employed to curb or reduce the severity of the damages caused by expansive soils on civil engineering facilities; among which are lime and cement stabilization [9, 13, 15].

Lime and cement are widely used for treatment of cohesive soils with expansive properties due to their effectiveness in reducing expansive properties, increase strength, decrease plasticity index, swell and shrinkage potential and controlling volume change, [12]. Lime has, however, been considered to be more appropriate for the stabilization of clay soils having fine contents in excess of 25% as it makes the soils more friable, less plastic and hence easier to work.

The reactions of lime with soils lead to strength gain. The strength gain arises chiefly from chemical reactions between the lime, clay minerals and amorphous constituent in the soil. When these are absent or present in small amounts, use has been made of lime together with a pozzolana. Pozzolanic material such as bagasse ash, fly ash, rise husk ash, coconut husk ash etc. have been extensively employed in admixture with lime and cement for stabilization of soils, [2,3, 4, 7, 8, 12, 14].

Bagasse ash has been reported to possess pozzolanic properties. It was reported that bagasse ash contains a large amount of silica and other relevant oxides which enhance good pozzolanic activity [5, 6]. The ash has been used alone or as admixture with lime and cement to stabilize laterite and black cotton soils [2, 12, 13, 14].

Considering the daily increase in the prices of cement and lime in a developing country like Ethiopia, the effective utilization of bagasse ash for engineering purpose is of significant economic importance. A successful employment of bagasse ash as admixture in lime stabilization, would lead to reduction in the amount of lime that may be required for a given project; hence a cut in the cost of the project. This is in addition to ridding the environment of the deleterious effect of these wastes on the environment.

The main objective of this research is to evaluate the effect of bagasse ash and lime and their combination on the properties of the expansive soil using Atterberg, compaction and CBR.

MATERIALS AND METHODS

Materials

Expansive Soil

The Expansive soil sample used for this research work is collected from Addis Ababa, Bole Sub City at 8º 59' 38.42''N and 38º 47' 13.09''E from one test pit. The soil is grayish black and highly plastic clay. A disturbed sample is collected from a test pit at a depth below 1.5m below the natural ground level in order to avoid the inclusion of organic matter.

Bagasse Ash

Waste bagasse ash was obtained from Wonji sugar factory which is located in Eastern Ethiopia in Oromiya Regional State.

Table 1: Oxide composition of bagasse ash (Hailu, B., 2011)

Constituents	% composition
SiO_2	65.58
Al_2O_3	5.87
Fe_2O_3	4.32
CaO	1.78
MgO	1.23
K_2O	6.41
Na_2O	1.02
P_2O_5	1.35
SO_3	0.18
Cl_2	< 0.1
MnO	0.05
TiO_2	0.25
L.O.I	10.48

Lime

The lime used in this study was purchased from the open market from authorized dealers in Diredawa.

Methods

The methods used for this study are summarized in Table 2 below.

Table 2: Methods adopted for the study

Name of test	Methods adopted
Particle size distribution	AASHTO T88-90
Specific gravity	AASHTO T100-93
Atterberg limit	AASHTO T89-90
Free swell	Holts and Gibbs
Free swell index	IS: 2720 (part 40)
Free swell ratio	Sridharan & Prakash
Compaction	AASHTO T99-94
CBR	AASHTO T193-93

TEST RESULTS AND DISCUSSIONS

Geotechnical Properties of Natural Soil

The following table shows the properties of natural soil before stabilization..

Table 3: Geotechnical properties of Natural Soil

Property	Quantity
% passing No. 200 sieve	98.8
Liquid limit, %	119.5
Plastic limit, %	41.4
Plasticity index, %	78.1
AASHTO soil classification	A-7-5
Specific gravity	2.79
Free swell, %	210
Free swell index, %	163.6
Free swell ratio, %	2.64
Maximum dry density, g/cm^3	1.26
Optimum moisture content, %	32.2
Soaked CBR value, %	0.91
Unsoaked CBR value, %	15.5
CBR-swell,%	11.83
Colour	grayish black

EFFECT OF LIME AND BAGASSE ON NATURAL SOIL

A. Plasticity Index

Variations of plasticity index with the addition of 3% lime, 15% bagasse ash and 3% lime in combination with/plus 15% bagasse ash are presented in Fig. 1. When black cotton soil treated with 3% lime the plasticity index decreased from a natural soil value of 78.1% to 34.6% for uncured sample and to 33.1% for 7 days air cured samples. While with the addition of 15% bagasse ash the plasticity index decreased from a natural soil value of 78.1% to 71.5% for uncured samples and to 66.7% for 7 days cured soil samples.

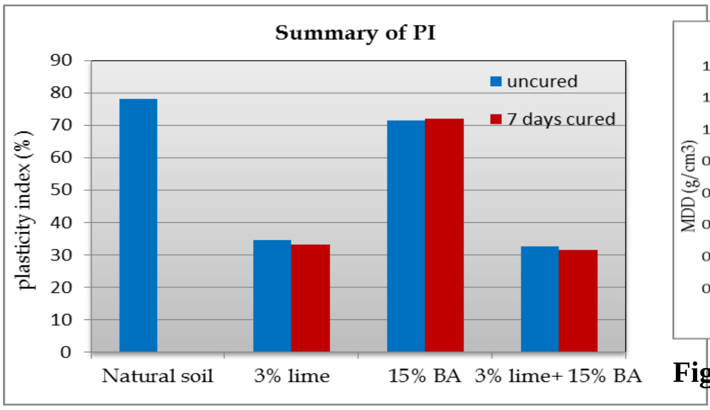

Fig. 1: Effect of stabilizers on plasticity index

For a similar class soil, the plastic limit decreased from a value of 78.1% to 32.5% without curing and to 31.6% with 7 days cured samples for the addition of 3% lime in combination with 15% bagasse ash.

The reduction in plasticity index is mainly due to the calcium available for cation exchange to take place and this effect could also be attributed to the combined action of partial replacement of plastic soil particles with non-plastic particles of bagasse ash, and the ionic exchange of lime and clay minerals of the soil. These led to flocculation and agglomeration of the clay particles which in turn reduce the plasticity of the treated soil.

B. Compaction Characteristics

Maximum Dry Density

The effects of bagasse ash on the maximum dry density in mixture of the soil-lime, soil-bagasse ash and soil-lime-bagasse ash are shown in Fig. 2. As shown in the figure, for uncured soil samples maximum dry density decreases for all mixes from a natural soil value of 1.26g/cm^3 to 1.23g/cm^3, 1.15g/cm^3 and 0.98g/cm^3 with the addition of 3% lime, 15% bagasse ash and 3% lime plus 15% bagasse ash respectively . For 7 days air cured soil sample maximum dry density decreases

for all mixes from a natural soil value of 1.26g/cm^3 to 1.14g/cm^3, 1.05g/cm^3 and 0.95g/cm^3 with the addition of 3% lime, 15% bagasse ash and 3% lime plus15% bagasse ash respectively. The addition of lime and bagasse ash together led to a higher decrease of the maximum dry density compared to the addition of lime and bagasse ash separately.

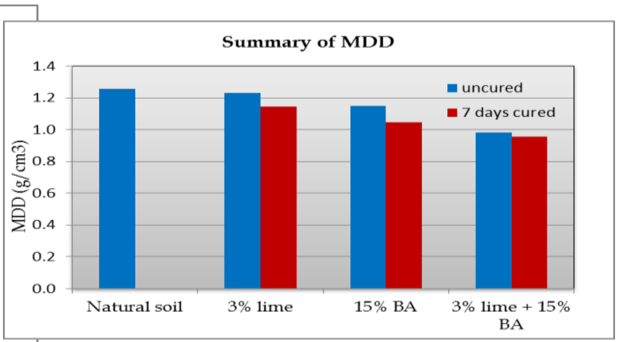

Fig. 2: Effect of stabilizers on maximum dry density

Optimum Moisture Content

The effects of bagasse ash on the optimum moisture content for the soil-lime, soil-bagasse ash and soil-lime-bagasse ash mixtures are shown in Fig. 3. As shown in the figure, for uncured soil sample optimum moisture content increases for all mixes from a natural soil value of 32.2% to 41.0%, 43.2% and 52.2% with the addition of 3% lime, 15% bagasse ash and 3% lime plus 15% bagasse ash respectively. For 7 days air cured soil samples optimum moisture content increases for all mixes from a natural soil value of 32.2% to 46.9%, 50.2% and 53.1% with the addition of 3% lime, 15% bagasse ash and 3% lime plus 15% bagasse ash respectively. The addition of lime and bagasse ash together led to a more increase of the optimum moisture content compared to the addition of lime and bagasse ash separately.

The increase in OMC is due to pozzolanic reaction of silica and alumina in bagasse ash and soil with calcium of the lime to form calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH) which are the cementing agents. Additional water is also required for wetting the large surface area of the fine bagasse ash particles or is absorbed by the fine particles of the bagasse ash.

The advantage of the increase in OMC and corresponding decrease in MDD of the soil is that it allows compaction to be easily achieved with wet soil. Thus, there is less of a need for the soil to be dried to lower moisture content prior to compaction in the field.

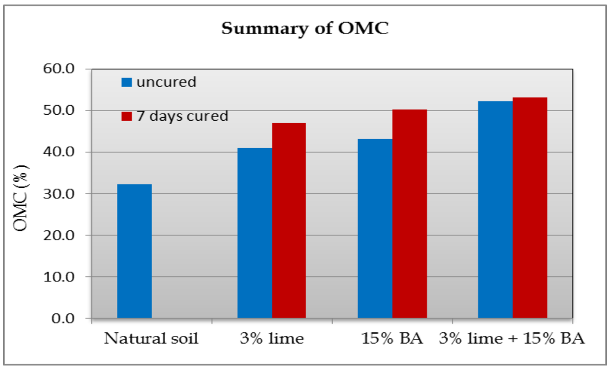

Fig. 3: Effect of stabilizers on optimum moisture content

C. CBR and CBR-swell

CBR values

As shown in the Fig. 4, the uncured CBR value increases for all mixes from a natural soil value of 0.91% to 9.73%, to 1.55% and to 22.51% with the addition of 3% lime, 15% bagasse ash and 3% lime plus 15% bagasse ash respectively. For 7 days air curing period the CBR values increased from the natural soil value of 0.91% to 23.83%, to 1.78% and to 32.9% with the addition of 3% lime, 15% bagasse ash and 3% lime plus 15% bagasse ash respectively. The addition of lime and bagasse ash together led to a more increase of the CBR value compared to the addition of lime and bagasse ash separately.

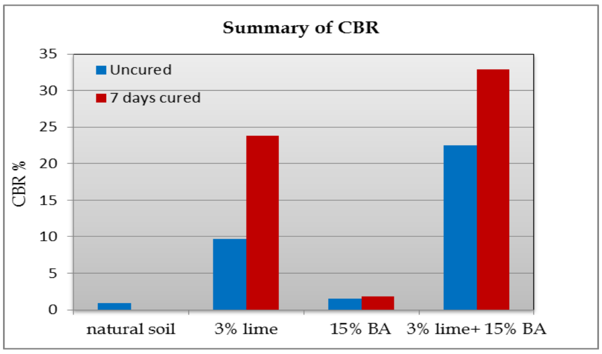

Fig. 4: Effect of stabilizers on CBR values

This increase was as a result of the formation of cementitious compounds, calcium-silicate-hydrates (CSH) and calcium-aluminate-hydrates (CAH), by calcium from lime and the readily available silica and/or alumina from both the soil and bagasse ash. CSH and CAH are cementitious products similar to those formed in portland cement. They form the matrix that contributes to the strength of stabilized soil layers.

It was also observed that the CBR value increased with curing age for all mixes. This is attributed to the pozzolanic reaction between the lime, soil and bagasse ash resulting in the formation of more cementitious compounds. Big differences in CBR values between cured and uncured sample for lime and lime plus bagasse ash magnify the importance of curing.

CBR- Swell

As shown in the Fig. 5, the uncured CBR-swell decreases for all mixes from a natural soil value of 11.83% to 6.07%, to 7.56% and to 2.15% with the addition of 3% lime, 15% bagasse ash and 3% lime plus 15% bagasse ash respectively.

For 7 days air curing period the CBR-swell decreased from the natural soil value of 11.83% to 0.95%, to 6.78% and to 0.26% with the addition of 3% lime, 15% bagasse ash and 3% lime plus 15% bagasse ash respectively. The addition of lime and bagasse ash together led to a higher decrease of the CBR-swell value compared to the addition of lime and bagasse ash separately.

The decrease in CBR-swell of expansive soil is due cation exchange between the soil and the additives and flocculation and agglomeration of the soil particles. This is also due to replacement of some of the volume that is previously occupied by expansive clay minerals by bagasse ash.

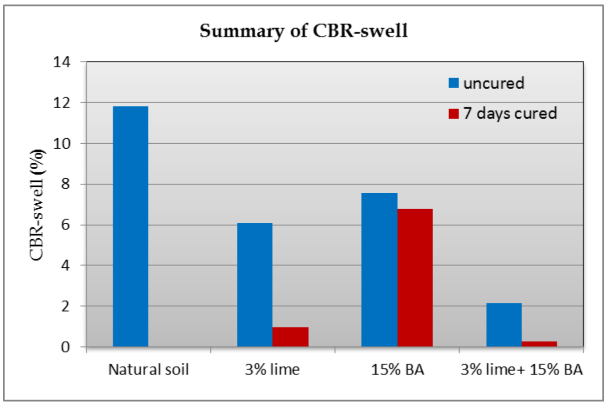

Fig. 5: Effect of stabilizers on CBR-swell

CONCLUSION

The plasticity index significantly decreased with addition of lime or bagasse ash combined with lime. However, the addition of bagasse ash alone has a minor effect on the plasticity index of the expansive soil.

- The maximum dry density of the stabilized soil decreases with addition of lime, bagasse ash and bagasse ash combined with lime. But the decrease is higher with the addition of lime in combination/combined with bagasse ash.

- The addition of lime and lime in combination with bagasse ash improved the CBR of the soil. The improvement is more significant with curing. But bagasse ash alone has a minor effect on the CBR value. The combination bagasse ash-lime can strongly improve the strength of the expansive soil.
- Combining two locally available materials (bagasse ash and lime) can effectively improve the properties of expansive soil.

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