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National Headquarters:
National Engineering Centre
Off National Mosque-Labour House Road,
Central Business Area,
Abuja, Nigeria.
E-mail: nsehqr@linkserve.com
nsehqrs@yahoo.co.uk
Website: *www.nse.org.ng*
Tel: 234-9-6735096
234-1-4766686

Lagos Office
1, Engineering Close,
P. O. Box 72667
Victoria Island, Lagos.
Tel: 01-2617349, 4709006
E-mail: nsehqr@linkserve.com
nsehqrs@yahoo.co.uk

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NSE TECHNICAL TRANSACTION VOL 43, NO 2, April-June, 2008 K.J Osinubi,. and A. M. Mustapha.

EFFECT OF ENERGY LEVEL ON CEMENT-SUGARCANE BAGASSE ASH ADMIXTURE ON LATERITE

By

Osinubi, K. J.*, and Mustapha, A.M.**
**Department Civil Engineering,*
Ahmadu Bello University, Zaria
***Department Civil Engineering*
Federal University of Technology, Minna

ABSTRACT

Laterite classified as A-7-6 and CL according to AASHTO and Unified Soil Classification systems, respectively, was treated with cement and sugarcane bagasse ash (SCBA) admixture. Specimens were compacted at three energy levels –British Standard Light (BSL), West African Standard (WAS) and British Standard Heavy (BSH) – which simulate the various compaction energies that can be encountered under field conditions. The effect of compaction energy levels on the geotechnical properties of the stabilized soil was studied. The maximum dry density (MDD), California bearing ratio (CBR) and unconfined compressive strength (UCS) of treated soil generally increased with higher compaction energies and dosages of additives. The durability of the soil-cement-bagasse ash specimens which was assessed by immersion in water to determine resistance to loss in strength improved with the addition of up to 6% bagasse ash content for specific cement contents. For the optimal treatment of the deficient soil additive combinations of 2% cement/6% bagasse ash and 6% cement/6% bagasse ash are recommended for mixtures compacted with the BSL effort for lightly(CB2) and heavily(CB1) trafficked roads, respectively. However, higher compaction energies can be employed in order to reduce the quantities of additives and still achieve the same strength and durability

INTRODUCTION

In tropical countries, including Nigeria, a lot of laterite gravels and pisoliths occur which are good for gravel roads (Osinubi and Bajeh, 1994). However, there are instances when a laterite may contain a substantial amount of clay minerals that its strength and stability cannot be guaranteed under load especially in the presence of moisture. These types of laterite are common in many tropical regions (e.g. Zaria area) where in most cases sourcing for alternative soil may prove economically unwise but rather to improve the available lateritic soil to meet the desired objective. Soil improvement could be by modification or stabilization or both. Soil modification is the addition of a modifier (cement, lime, etc) to a soil to change its chemical properties. Soil stabilization however, is the treatment of soils to enable their strength and durability to be improved such that they become totally suitable for construction beyond their classification if left untreated. However, the strength and stability developed due to stabilization of soils depend mainly on the compaction energy applied.

Cement and lime are the common additives used for chemical stabilization of deficient lateritic soils. However, there are instances where the lacking properties of a soil cannot be restored by a single chemical additive like cement, lime, etc or a required strength cannot be gained by economic amount of a single additive. In these circumstances, two or more chemical additives could be required to restore the lacking properties or required strength with economic amount of an additive. Sugar cane bagasse ash (SCBA) is obtained from the burning of the Fibrous residue of sugarcane processing from sugar companies. Misari et al. (1998) reported that Nigeria has a potential of producing about 270,000 tonnes of bagasse ash per annum. The ash has been categorized under pozzolana with about 60-70% silica and about 9% alumina and 3% iron oxide (Ogbonyomi, 1998).Therefore, the aim of this study was to determine the effect of compaction energy level on cement-SCBA admixture stabilization of Laterite.

LOCATION AND GEOLOGY OF STUDY AREA

The soil sample used in this study was taken from a borrow pit along Zaria - Sokoto road (Longitude 7°36'E Latitude 11° 4'N) using the method of disturbed sampling. A study of the soil and geological maps of Nigeria shows that the soil from this pit belongs to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks (Osinubi, 1998a, b)

ADMIXTURE STABILIZATION

Singh (1991) defines stabilization as the combination of soils and or other additives in such a way that, when it is compacted under specified conditions and to specified extent, would undergo material change in its properties and would remain in its stable compacted state without undergoing any change under the effect of exposure to weather and traffic. However, there are instances where the lacking properties of a particular soil cannot be restored by a single additive like cement, lime, bitumen etc, or a required strength cannot be gained by an economic amount of a single additive. For instance, cement, which is a readily available soil stabilization additive in Nigeria, cannot be used economically on very soft clays like the black cotton clays (Yoder and Witczak, 1975). But addition of lime to this type of clay can help to increase its workability and reduce the amount of cement that would have been required for efficient stabilization of that clay.

Long term increase in strength due to treatment of soil with chemical additive can also be achieved with the addition of any pozzolanic material with cement. Cementitious compounds are produced due to the reaction between the pozzolana and the lime librated during the hydration reaction of cement. This time dependant reaction has prompted some researchers to employ new evaluation criteria for soil stabilization using a combination of an additive and a pozzolana since the only criteria available are for cement and lime. One of the recent laboratory trials to achieve this objective is that of Osinubi (1999), who evolved an evaluation criterion for cement stabilized residual black cotton soil when lime is used as an admixture. It was concluded that, due to time- dependant increase in strength and attendant high durability due to enhanced pozzolanic reaction of the soil-lime-cement mixture, an unconfined compressive strength (UCS) of 1235kN/m^2 and a California bearing ratio (CBR) of 55% are recommended as evaluation criteria as against the UCS of 1720 kN/m^2 and CBR of 180% recommended by BS 1924 (1990) and Nigerian General Specification (1997).

Researchers (Toro, 1998; Osinubi, 1999, Osinubi and Medubi, 1997; Medjo and Riskowiski, 2004; Osinubi et al., 2007a,b) conducted laboratory studies on admixture stabilization of various chemical additives and recorded substantial increases in CBR and UCS after curing. However, the variations of MDD and OMC of these mixtures with increase in admixture contents are not consistent with those of single additives. Rather, they increased and decreased at no constant additive contents due to complex reactions between the additives and the soil stabilized.

METHODS OF TESTING

Laterite samples were stabilized with cement contents of 2, 4, 6 and 8% admixed with 2, 4, 6 and 8% bagasse ash content by dry weight of soil. British Standard Light (BSL), West

African Standard (WAS) and British Standard Heavy (BSH) compaction energies were used to determine the OMC and MDD of each specimen and simulate the range of compactive efforts that can be used under field conditions.

Curing of the compacted soil-cement-SCBA specimens for CBR test was limited to six days unsoaked and one day soaking before testing as recommended by the Nigerian General Specification (1997). The curing for UCS test was limited to 7 and 14 days for each specimen. However, the following tests were carried out on the natural lateritic soil according to procedures outlined in BS 1377(1990):

i. Particle size distribution
ii. Atterberg limits
iii. Moisture-density relationship
iv. Unconfined compressive strength (UCS) and
v California bearing ratio (CBR)

Also, tests including compaction, CBR and UCS were carried out on stabilized specimen according to BS 1924 (1990). The durability of the specimens were determined using UCS specimens cured for 7 days after which the specimens were immersed in water for another 7 days and compared with specimen cured for 14 days to determine the resistance to loss in strength after immersion in water.

DISCUSSION OF TEST RESULTS

The identification and classification test results for the natural soil (see Table 1 and Fig. 1) shows that the soil classifies under the A–7-6 subgroup using the AASHTO Soil classification system and also CL, clay of low plasticity according to Unified Soil Classification System (USCS). This soil, which particle size distribution is shown in Fig. 1, in its natural state is rated poor for sub base and base courses in pavement structure according to AASHTO soil classification system and the Nigerian General Specification (1997) and therefore would require stabilization to improve its strength and durability.

Oxide Composition of Sugarcane Bagasse Ash (SCBA)

X- ray fluorescence analysis used to determine the oxide composition of the sugarcane bagasse ash (SCBA) detected 70.14% of the oxides (i.e., Fe_2O_3 = 3.96%; SiO_2 = 57.95% and Al_2O_3 = 8.23%). This value is within the required minimum value of 70% specified for pozzolana (ASTM C618 – 78, 1978). The value is lower than that obtained by Ogbonyomi (1998). The difference in value is probably due to the method of preparation of the ash and the species of the sugarcane used.

Compaction Characteristics

The variations of MDD with SCBA content admixed with specific percentages of cement are presented in Fig. 2. Generally, MDD increased with higher compaction energy in the order – BSL – WAS – BSH compaction and OMC decreased (see Fig. 3) in the same order. This trend is in agreement with Osinubi (1998a) who studied the influence of BSL and WAS compactive efforts on the compaction and strength characteristics of lateritic soil treated with lime. Higher MDD was recorded for WAS compactive effort compared to the BSL compactive effort with corresponding decrease in OMC in the same order.

Strength Characteristics

California bearing ratio

The variation of CBR with SCBA content for specific percentages of cement is shown in Figure 4. Addition of cement and SCBA to the natural soil improved its CBR values from 5, 7 and 12% recorded at BSL, WAS and BSH compactions, respectively, to 170, 180 and 210%, respectively for the compactive efforts. This trend is in agreement with Osinubi (2000) who studied the influence of compaction energy levels on cement treated soils. Although BSH compaction energy level was not included in the study, there was increase in CBR from BSL to WAS compaction energy level. The reason for this trend is the increase in dry density in the same order BSL–WAS–BSH energy levels.

Peak CBR values were recorded at 6% SCBA for specific cement contents, except for soil-4% cement-4% SCBA mixture compacted at BSH energy level. At BSH compaction energy level, no increase in CBR value with compaction energy level occurred at cement contents up to 4%. However, increase in CBR with higher compaction energy levels was recorded at cement contents between 6 and 8%. This is due to the presence of predominant high specific gravity cement coupled with the hydration reactions caused by the little water available in the system. However, the deviation of soil – 4% cement – 4% SCBA mixture compacted at BSH from other results could be attributed to insufficient water in the system for sufficient hydration of cement to form cementitious compounds. The higher dry density that would have aided the achievement of higher strength was obstructed by a predominant proportion of low specific gravity SCBA in the soil-cement – SCBA mixtures.

Going by the CBR value of 180% recommended by the Nigeria General Specification (1997) to be attained in the laboratory for cement stabilized materials to be constructed by mix-in-place method, only the peak CBR values for soil treated with 8% cement – 6% SCBA admixture and compacted at WAS (180%) and BSH 8% cement – 6% SCBA admixture energy level (210%) satisfied the requirement. The peak CBR value 170% at BSL compaction energy level could not satisfy the requirement. However, this peak CBR value coupled with the 170% CBR recorded for 6% cement – 6% SCBA admixture at WAS compactive effort and 175% CBR recorded for 6% cement – 8% SCBA admixture at BSH compaction energy level may all attain the required 180% CBR at a later age due to the time - dependent pozzolanic reaction between the calcium hydroxide $Ca(OH)_2$ released from the hydration reaction of cement and the SCBA.

In view of Ola (1974) suggestion that CBR value of 60 – 80% be adopted for base materials and 20 – 30% for sub base materials of lightly trafficked roads with superior residual soil when compacted at 95% of BSH, all the peak CBR values recorded for treated specimens satisfy the requirement for base course of lightly trafficked roads except specimens containing 2% cement compacted at BSL energy with a value of 70%. However, this value may attain the 80% with age due to time - dependent pozzolanic reaction between librated lime and SCBA.

Unconfined compressive strength

Variation of UCS with SCBA content for specific cement contents at the BSL, WAS and BSH compaction energies for 7days curing period are shown in Fig. 5. There was substantial improvement in the UCS of the natural soil from 610, 860 and 1020 kN\m^2 recorded at BSL, WAS and BSH compaction energies, respectively, to the corresponding peak UCS values of 4800, 5310 and 6530 kN/m^2, respectively, when treated with cement and SCBA. Higher peak UCS values of 5510, 5710 and 7550kN/m^2 were recorded at 14days curing period. (see Fig. 6) at BSL, WAS and BSH compaction energy levels, respectively. These increases were due to the initial reaction of cement with soil that produced cementation compounds and the subsequent secondary time-dependent pozzolanic reaction due to SCBA that resulted in improvement of strength (Osinubi and Medubi, 1997).

Road Note 31 (1993) recommends the UCS range of 3000 – 6000 kN/m^2 for specimen cured for 7 days as road base for heavily trafficked roads (CB1) and 1500 – 3000 kN/m^2 as road base for lightly trafficked roads (CB2). Singh (1991) also recommends a 7 day UCS value of 1720kN/m^2 for lightly trafficked road bases (CB2) and from 2750 – 3450 kN/m^2 for heavily trafficked road bases (CBI). Nigerian General Specification (1997) also recommends a 7 day UCS value of 1720kN/m^2 for lightly trafficked road bases. If a UCS value of 3450 kN/m^2 is recommended for heavily trafficked road bases which is in an agreeable range with both the Road Note 31 (1993) and Singh (1991), only the peak UCS values of 4380 kN/m^2 at 6% cement / 6% SCBA as well as 4800 kN/m^2 at 8% cement/6% SCBA are adequate for (CBI) road base at BSL compaction level. At WAS compaction energy level however, the peak UCS values of 3780 kN/m^2 at 4% cement/6% SCBA, 4580 kN/m^2 at 6% cement/6% SCBA and 5310kN/m^2 at 8% cement and 4% SCBA admixture are adequate for heavily trafficked (CBI) road bases. In a similar manner, peak UCS values of 3870, 5000 and 6520kN/m^2 at 4% cement/ 6% SCBA, 6% cement/6% SCBA and 8% cement/6% SCBA are equally adequate at BSH compaction level. The 1720 kN/m^2 recommended for lightly trafficked (CB2) road bases by Road Note 31 (1993), Singh (1991) and Nigeria General Specification (1997) after 7 days curing period was satisfied by peak UCS values at all cement and SCBA admixtures at the three energy levels studied. The minimum peak UCS values 2040, 2550 and 2650kN/m^2 occurred at 2% cement/6% SCBA at BSL, WAS and BSH compaction.

Durability

The durability of the treated soil was determined by the method of immersion in water in order to establish the resistance to loss in strength. This method is more appropriate to be used in tropical regions (Ola 1974). Variation of UCS for specimens cured for 7 days and soaked for another 7 days with varied SCBA and specific cement contents at the three energy levels considered are shown in Fig. 7

The minimum resistances to loss in strength of 53.6 (soil-2% cement/8% bagasse ash), 46.7 (soil-2% cement/6% bagasse ash) and 54.6% (soil-4% cement/8% bagasse ash) corresponding losses in strength of 46.4, 53.3 and 45.4% were recorded for specimens compacted at the energies of BSL, WAS and BSH, respectively. Peak resistances to loss in strength of 81.5, 93 and 86.5% (i.e., 18.5, 7.0 and 13.5% losses in strength, respectively) were obtained for soil-6% cement/8% bagasse ash mixtures compacted at the energies of the

BSL, WAS and BSH, respectively. The minimum durability values are not adequate going by the 80% resistance to loss in strength suggested by Ola (1974) for superior residual soil specimens immersed in water for only 4 days after the first 7 days curing period. However, adequate durability values can be chosen for additive combinations between the minimum and peak values. Furthermore, increased compaction energy can be employed in order to reduce the quantities of additives and still achieve the same strength and durability.

CONCLUSION AND RECOMMENDATIONS

The geotechnical properties of the natural and stabilized soils improved with higher compaction energy levels as shown in the compaction, CBR and UCS tests results. Hence increased compaction can be employed to save stabilization additives and still achieve the same strength and stability.

For the optimal treatment of the deficient soil additive combinations of 2% cement/6% bagasse ash (90% resistance to loss in strength) and 6% cement/6% bagasse ash (76% resistance to loss in strength) are recommended for mixtures compacted with the BSL effort for lightly(CB2) and heavily(CB1) trafficked roads, respectively. In view of the harsher immersion condition and the expected time-dependent gain in strength the 76% resistance to loss in strength can be accepted as being adequate. Furthermore, the BSL compactive effort is adopted because it can easily be achieved under field condition.

Property	Quantity
Natural moisture content (%)	6.55
Percent Passing BS No. 200 sieve	62.5
Liquid limit (%)	41.0
Plastic limit (%)	18.0
Plasticity index (%)	23.0
Linear shrinkage (%)	8.93
Group index	12
AASHTO classification	A-7-6
USCS classification	CL
Specific gravity	2.69
Maximum Dry Density (Mg/m^3)	

British Standard Light compaction	1.841
West African Standard compaction	1.910
British Standard Heavy compaction	1.990
Optimum Moisture Content (%)	
British Standard Light compaction	15.2
West African Standard compaction	13.5
British Standard Heavy compaction	12.0
California Bearing Ratio (soaked) (%)	
British Standard Light compaction	5
West African Standard compaction	7
British Standard Heavy compaction	12
Unconfined Compressive Strength (kN/m^2)	
British Standard Light compaction	610
West African Standard compaction	860
British Standard Heavy compaction	1020
Organic matter content (%)	6.75
Colour	Reddish Brown

Table 1: Index Properties of the natural soil

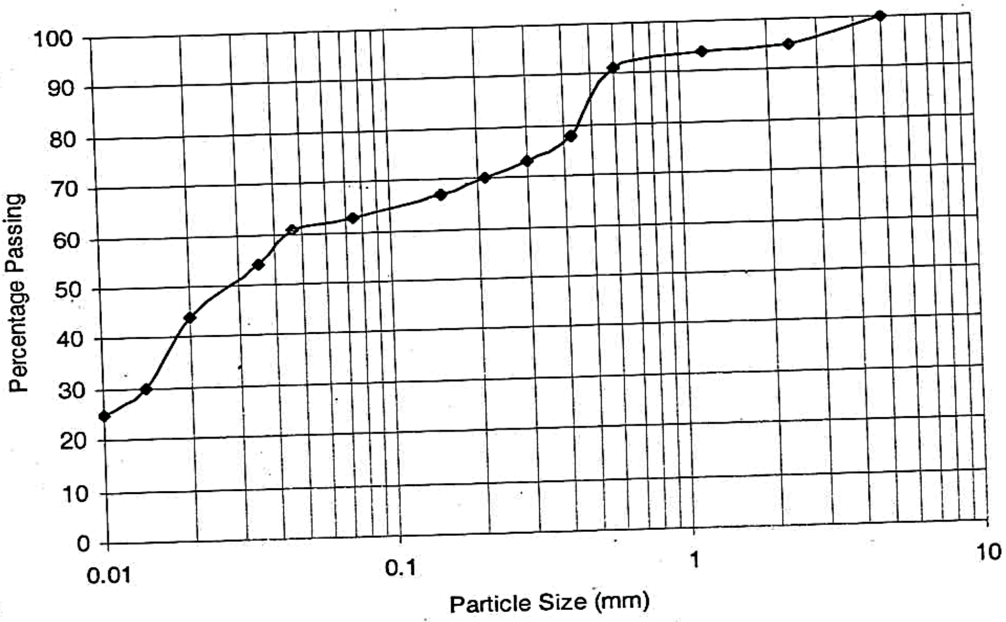


Figure 1: l Particle size distribution curve for the natural soil

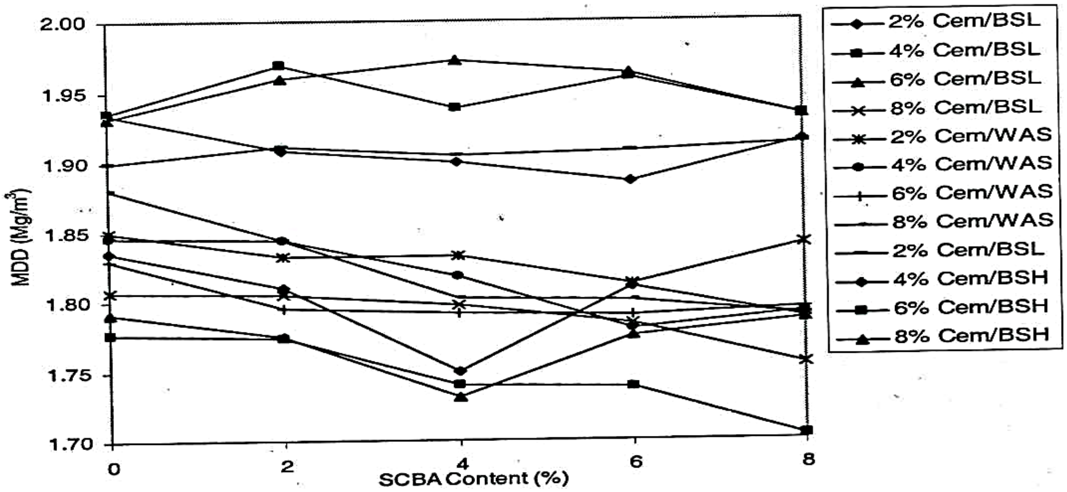


Table 1: Index Properties of the natural soil

Fig. 1 Particle size distribution curve for the natural soil.

Fig. 2 Variation of MDD with SCBA Content at BSL, WAS, and BSH Compaction Energy Level.

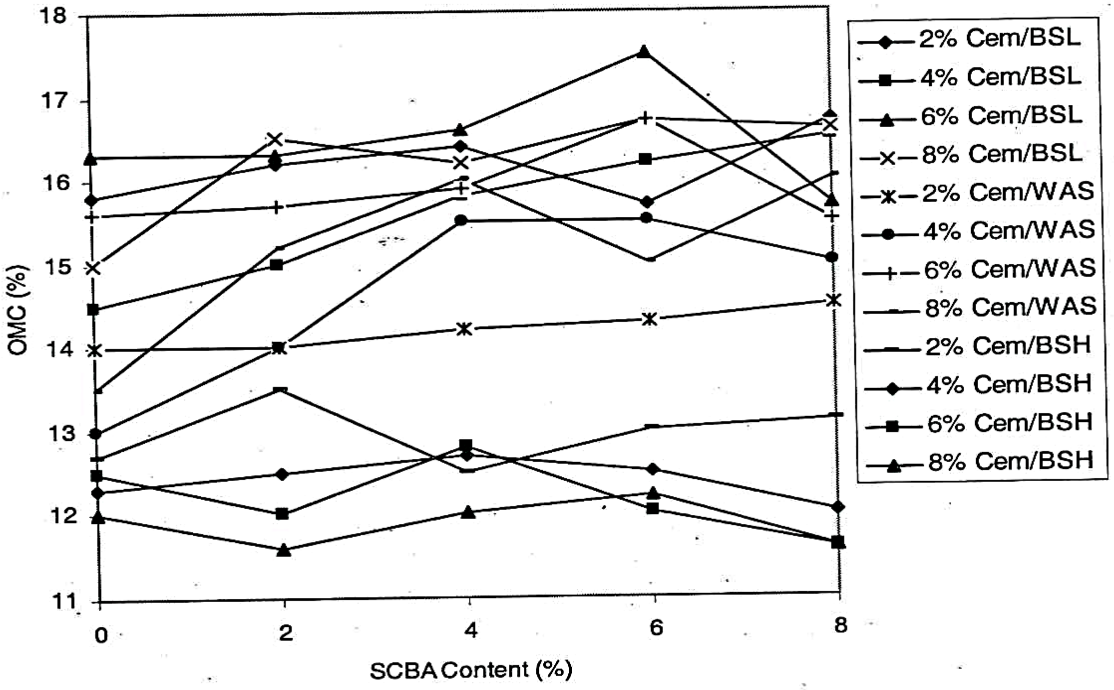
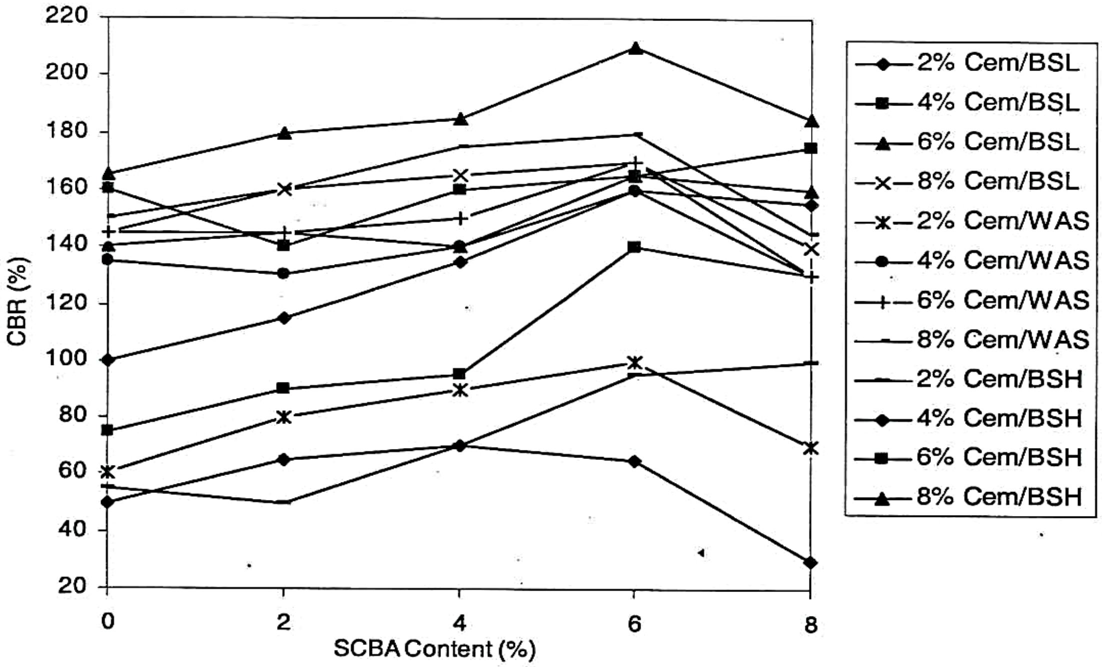


Fig. 3 Variation of OMC with SCBA Content at BSL, WAS and BSH Compaction Energy Levels

Fig. 4



Variation of CBR with SCBA Content at BSL, WAS and BSH Compaction Energy Levels

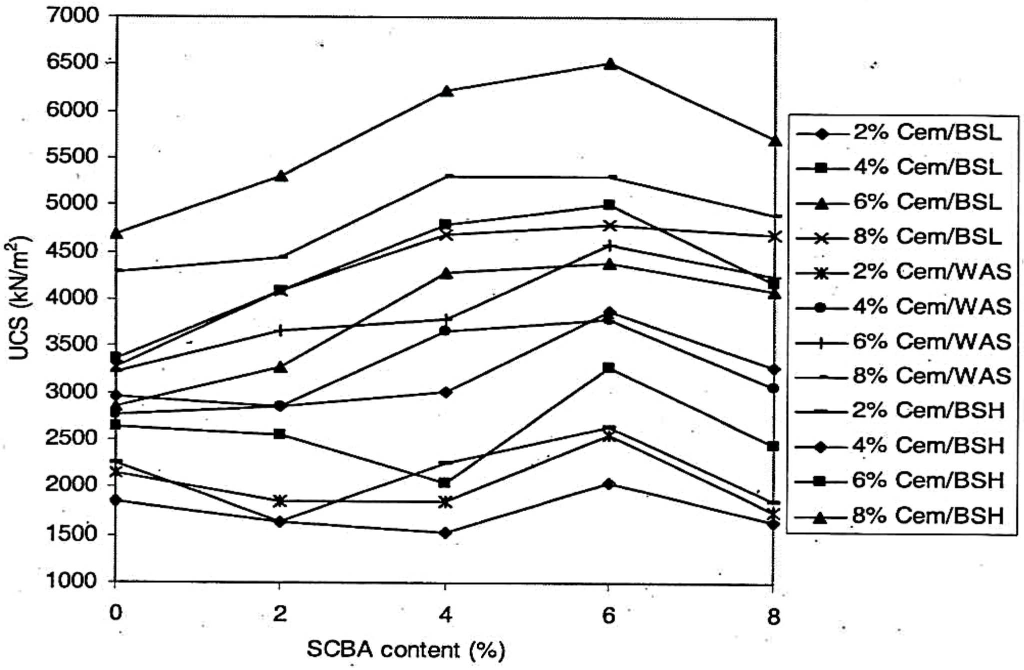


Fig. 5 Variation of UCS for 7 days Curing with SCBA Content at BSL, WAS, and BSH Compaction Energy Levels

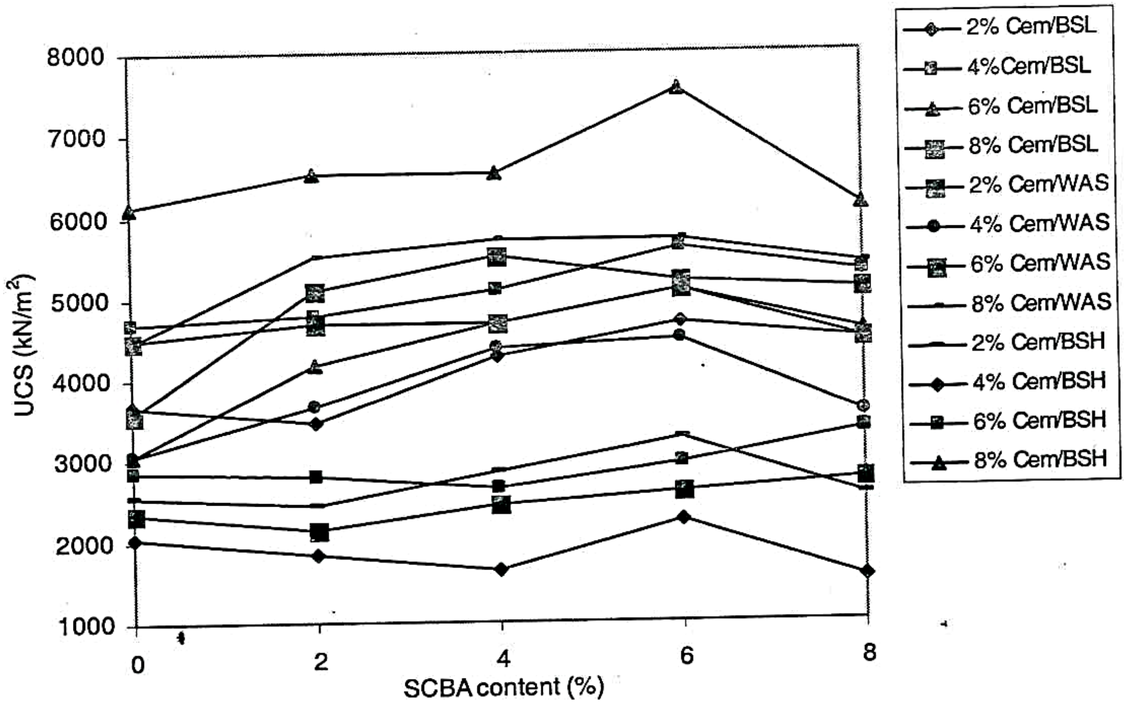


Fig. 6 Variation of UCS for 14 days Curing with SCBA at BSL, WAS and BSH Compaction Energy Level

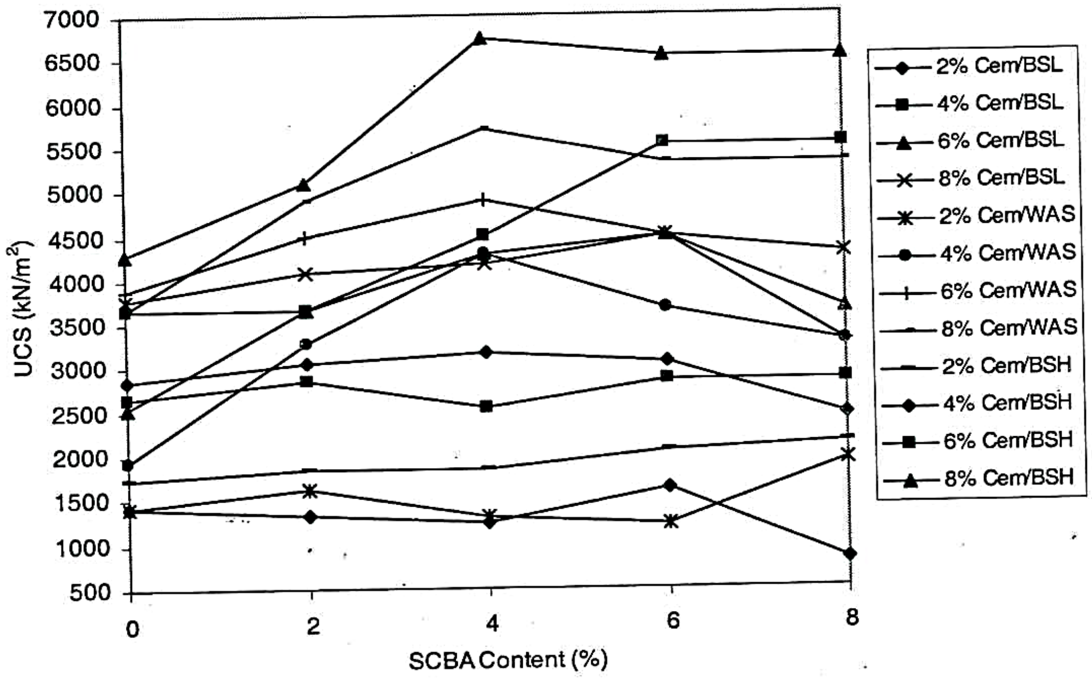


Fig. 7 Variation of UCS for 7 days unsoaked + 7 days soaked curing period with SCBA

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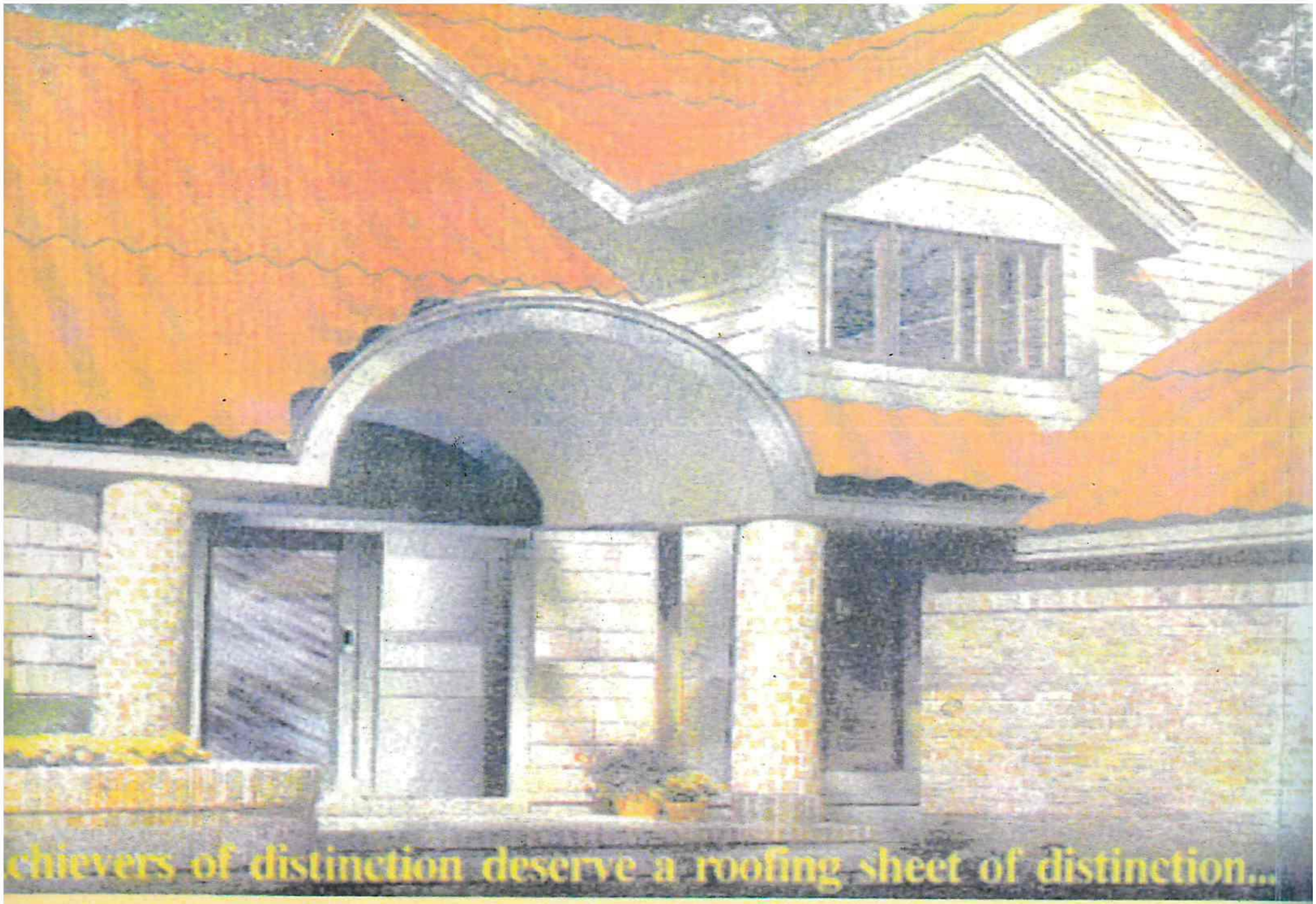
chievers of distinction deserve a roofing sheet of distinction...