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تثبيت التربة لأعمال الرصف باستخدام الأسفلت المعالج ووماد قصب السكر

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الخلاصـة

أجريت دراسة معملية لتقييم قوة استقرار التربة مع رصيف أسفلت المعاد تدويره و RAP ورماد قصب السكر و SCBA. وتم خلط التربة مع اتيرايت RAP بنسبة 40/60 ومعالج مع SCBA بنسبة 8 ,6 ,4 ,2 ,0 و 10% وزنا من خليط التربة و RAP. وجرى تحليل حجم الجسيمات، واختبار الضغط وقوة الضغط غير المحصورة، و UCS، ونسبة كاليفورنيا للتحمل، و CBR، وأجريت الاختبارات على العينات المتعددة. النتائج تبين أن إضافة RAP تقلل المحتوى الأمثل للرطوبة و OMC ويزيد الحد الأقصى للكثافة الجافة، و MDD، من العينات بالمقارنة مع التربة الطبيعية مع إضافة SCBA حتى نسبة 4% والزيادة في MDD. كلما زادت كمية SCBA انخفضت كمية MDD. كلما زادت كمية OMC زادت كمية UCS وكذلك زادت معها CBR والمعالج SCBA على التوالي. تم خمر العينات للحصول على نتائج لمدة 24 ساعة وأدت الى خفض القيم CBR. وبناء على النتائج المختبرية التي تم الحصول عليها واستنادا إلى معايير القوة للتربة والجير اعتمدت في هذه الدراسة، ولوحظ أن 6 إلى 8% من المعالج SCBA الناتج من خليط التربة وRAP حققت أفضل النتائج ملبية لمتطلبات القاعدة الأساسية و10% من المعالج SCBA يعطي نتائج أفضل لتلبية متطلبات الطرق ذات كثافة قليلة.

Stabilization of laterite soil using reclaimed asphalt pavement and sugarcane bagasse ash for pavement construction

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ABSTRACT

A laboratory study was carried out to evaluate the strength of laterite soil stabilized with recycled asphalt pavement (RAP) and sugarcane bagasse ash (SCBA). The laterite soil was mixed with RAP in 40/60 ratio and treated with SCBA at 0, 2, 4, 6, 8 and 10 % by weight of the soil-RAP mixture. Particle size analysis, compaction test, unconfined compressive strength, (UCS), and California bearing ratio (CBR), tests were carried out on the prepared specimens. The results obtained show that addition of RAP reduces the optimum moisture content, (OMC), and increases the maximum dry density (MDD) of the sample as compared with the natural soil while the addition of SCBA up to 4% results in further increase in MDD; further addition of SCBA results in reduced MDD whereas OMC increased with increasing SCBA. UCS and CBR increased with SCBA treatment and curing period respectively. Soaking of the specimens for 24 hours results in reduced CBR values. Based on the laboratory results obtained and based on the strength criteria for soil-lime adopted in this study, it was observed that 6 to 8% SCBA treatment of the soil-RAP mixture yielded the best results meeting the requirement for sub base course and 10% SCBA treatment gives the best results meeting the requirement for base course for light trafficked roads.

Keywords: California bearing ratio; laterite; maximum dry density; recycled asphalt pavement; sugarcane bagasse ash; unconfined compressive strength

INTRODUCTION

Base and sub-base layers of a flexible pavement structure are designed to transmit and distribute traffic loads to the sub-grade without causing undue stress or damage to the sub-grade. The materials used for the construction of these layers must have specified properties in terms of strength, in order to be considered for use.

In tropical and sub-tropical regions of the world, the dominant soils available for the construction of sub-base and base courses of flexible pavements are lateritic soils. These are used because of their abundance and cost effectiveness. However, not all of these soils are suitable for construction. Many road pavements constructed using these materials are either distressed or have failed completely within a short period of time. Ola (1974) reported that the defective nature of laterite soils in Nigeria are responsible for the failure of roads constructed using the soils. To overcome these problems, the strength must be improved by stabilization. Osinubi (1998b) reported that some lateritic soils do not require treatment to improve their load bearing capacity, but most laterites require some sort of stabilization prior to their use in road construction.

Soil stabilization is the use of mechanical means or addition of chemical additives to soil in order to improve the soil strength, bearing capacity and durability under adverse stress and moisture conditions. Mechanical stabilization includes soil compaction and densification by means of mechanical energy; various sorts of rollers, rammer and vibration techniques can be used. Other methods include mechanical analysis to determine the proportions of particle sizes to yield an optimal grading (ASTM, 1980b). Thus stabilization of soil can be achieved by adjusting the particle grading.

Chemical stabilization on the other hand is achieved by adding chemical additives such as lime and cement. Many studies have been conducted on stabilization of soils including laterite soils using cement and lime (Ingles and Metcalf, 1972; Osinubi, 1995; 1998b; 2000, 2001; Nicholson *et al.,* 1994).

Materials with pozzolanic properties such as industrial waste ashes (e.g. coal bottom ash, fly ash) as well as agricultural wastes ashes (e.g. rice husk ash, sugar cane bagasse ash, oil palm ash) have been used for admixture stabilization of soils (Mohammedbhai and Baguant, 1985; Osinubi and Medubi, 1998; Osinubi, 2000).

Sugar Cane Bagasse Ash (SCBA) is obtained by the incineration of the fibrous waste from the extraction of sugar cane juice. The ash is reported to be pozzolanic due to the presence of high proportions of silica. Mohammedbhai and Baguant (1985) reported that SCBA contains a large amount of silica (about 74%) and other relevant oxides such as Al_2O_3, 12.12%; Fe_2O_3, 12.12%; and CaO, 3.39%, which enhance good pozzolanic activity.

Reclaimed asphalt pavement (RAP) refers to removed and/or reprocessed pavement materials containing asphalt and aggregates. RAP has been used for different engineering applications including as an aggregate substitute material, for hot mix or cold mix asphalt pavements (Smith, 1980; Kallas, 1984; Decker and Young, 1996), as a granular base or sub-base aggregate (Hanks and Magni, 1989), and to produce a mechanically stabilized base or sub-base by increasing the aggregate content of the soil. RAP and fly ash have also been used to stabilize sub-grade soils for pavement construction (Rupnow, 2002). In Nigeria however, this material is usually dumped along the road sides without any engineering applications.

The objective of this study is to evaluate using laboratory test, the effect of RAP and SCBA treatment on laterite soil. The SCBA and RAP were used as chemical and mechanical stabilizers to stabilize the laterite soil. The RAP and laterite were mixed in a fixed proportion of 60% laterite soil and 40% RAP with the addition of SCBA in increments of 0, 2, 4, 6, 8 and 10% of the dry weight of the soil/RAP mixture. The choice of 60/40% laterite soil/RAP proportion is to have a soil/RAP mixture that will enable maximum utilization of RAP, which will go a long way in solving some of the environmental challenges caused by it and to achieving a level of stabilization of the laterite soil suitable for pavement construction. The laboratory tests carried out on the prepared samples include sieve analysis, compaction test using standard Proctor, unconfined compressive strength test, (UCS) and California bearing ration test, (CBR).

MATERIALS AND TEST METHODS

Materials

Laterite soil

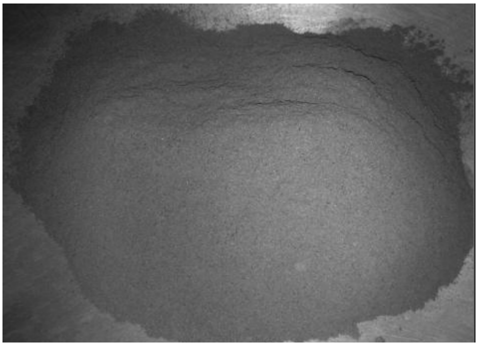
The laterite soil sample used for this study was collected in the Shika area of Zaria, Nigeria, along Zaria -Funtua Road from a borrow pit at longitude 7° 45ʼE, latitude 11° 15ʼN, south of the new Ahmadu Bello University Teaching Hospital. Disturbed samples were collected from a depth of 0.5m below the ground surface. The soils were sealed in bags and transported to the laboratory. Areola (1982) reported that laterite from this area belongs to the group of ferruginous tropical soils derived from acidic igneous and metamorphic rocks.

Bagasse ash

The bagasse ash used in this research was obtained from local sugar manufacturing mills in Anchau, Kaduna State. The ash was passed through British Standard sieve No. 200 sieve (75 µm aperture). Figure 1a is a picture of the sieved ash. The fraction passing sieve No.200 was collected and mixed with the soil/RAP mixture in increments of 0, 2, 4, 6, 8 and 10 % by weight of dry mixture to obtain the required specimens for testing.

Reclaimed Asphalt Pavement

The reclaimed asphalt pavement material used in this study was obtained from a scarified discarded pavement surface along Katsina – Kano Road (5Km from Katsina) in Katsina State, Nigeria. The RAP was crushed manually to obtain material passing through British Standard sieve No. 4 (4.75 mm). Figure 1b shows the RAP material as collected.



(a)

(b)

Fig. 1. (a) Sample of sugar cane bagasse and (b) Sample of reclaimed asphalt pavement

Testing Method

The oxide composition of the ash was determined using the method of energy dispersive X-Ray fluorescence (EDXRF). The result is shown in Table 1. It can be observed that the SCBA contains 63.47 % SO_3, 2.25% CaO, 16.55 % Al_2O_3, and 1.57 % Fe_2O_3 This result shows that the bagasse ash is a pozzolana belonging to Class F in accordance with ASTM C 618.

Table 1. Oxide composition of bagasse ash

Oxide	Cao	SiO_2	Al_2O_3	Fe_2O_3	Mn_2O_3	K_2O	TiO_2
Concentration %	2.25	63.47	16.55	1.57	0.26	3.00	1.27

Preliminary tests were carried out on the laterite soil in accordance with BS 1377 (1990) to determine the index and strength properties of the natural soil. The results of the tests are presented in Table 2. The particle size distributions of the laterite soil and the soil-RAP mix are shown in Figure 2.

The experimental samples were prepared by mixing soil/RAP in a 60/40% proportion and adding SCBA in increments of 0, 2, 4, 6, 8 and 10% of the dry weight of the soil/RAP mixture. Mixing was carried out by adding RAP to the soil and properly mixing in a bowl after which the appropriate amount of SCBA was added in percentage of the weight of the soil/RAP mixture. The whole mixture was then properly mixed to obtain a uniform mixture. Mixing was carried out at room temperature. Four samples were prepared for each of the six mixtures for the various tests.

Sample Compaction

Compaction test was carried out to determine the optimum moisture content (OMC) and maximum dry density (MDD) of each sample. Standard Proctor compactive effort was used. Figure 4 shows the moisture - density (compaction) curves for the various percent addition of SCBA.

Table 2. Index and strength properties of laterite soil

Properties	**Quantity**
Natural moisture content (%)	10.24
Liquid limit (%)	42.0
Plastic limit (%)	26.0
Plastic index (%)	16.0
Specific gravity (%)	2.62
Percentage passing BS 200 sieve (%)	51.8
AASHTO classification	A - 7 - 6
USCS classification	CL
Maximum dry density (Mg/m^3)	1.77
Optimum moisture content (%)	16.0
California Bearing Ratio (%)	7.0
Unconfined compressive strength (kN/m^2)	152
Color	Reddish-Brown

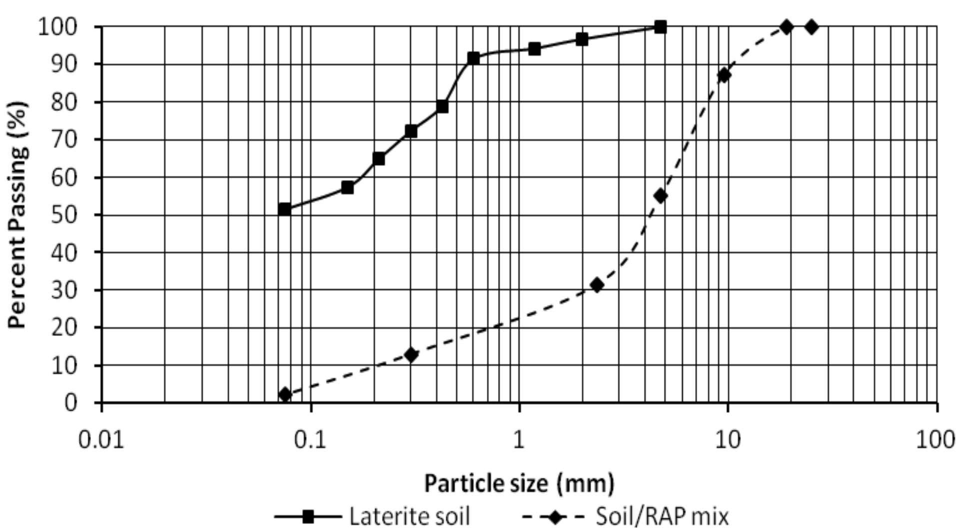


Fig. 2. Particle size distribution for laterite soil and soil-RAP mix

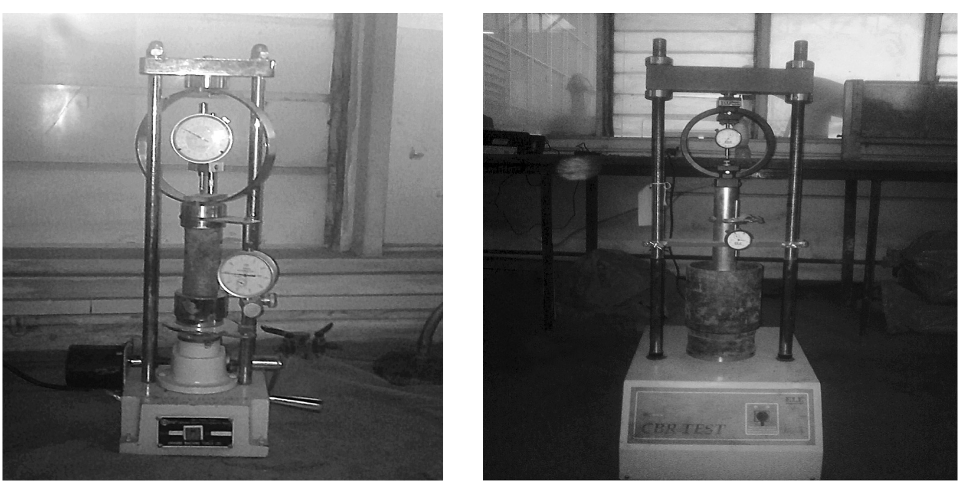
Unconfined compressive strength test

The unconfined compressive strength test was conducted on the samples in accordance with BS 1377(1990). Cylindrical samples 38mm in diameter and 76mm in height of soil/RAP mixture with various percentages of bagasse ash were compacted at different OMCs based on the moisture/density tests, wrapped in polythene bags and cured in a humidity room for 7 and 14 days respectively. At the end of the curing periods, the samples were unwrapped and subjected to steadily increasing axial compression until failure occurred. For each sample, three specimens were tested. The first test was considered as trial while the average of the remaining two successive results was taken provided the deviation was not more than 10% otherwise the maximum value was used. Figure 3a shows the specimen being tested.

California bearing ratio test

The California bearing ratio (CBR) is a penetrative test for the evaluation of subgrade strength of roads and pavements. The results from these tests are empirically correlated to help determine the thicknesses of pavement layers.

The tests were carried out in accordance with BS 1377 (1990), five kg samples were taken and mixed thoroughly with the appropriate percentage of water by weight. The percentage weight of water used was taken at the optimum moisture content obtained from the compaction tests . The specimens were cured for 6 days and immersed in water for 1 day in accordance with the Nigerian general specifications for bridge and roadworks (Nigerian, 1997). Figure 3b show the CBR test being conducted.



(a) (b)

Fig. 3. (a) UCS test of soil-RAP-SCBA mixture (b) CBR test of soil-RAP-SCBA mixture

RESULTS AND DISCUSSION

Physical properties

The results of the testing program conducted for the identification and classification of the lateritic soil (natural soil) are summarised in Table 2. The soil was classified as A-7-6 in accordance with AASHTO soil classification and lean clay, (CL) in accordance with the unified soil classification system, (USCS), respectively. Based on this classification and on the Nigerian general specification for bridge and road works (Nigerian, 1997), the soil is considered unsuitable for sub-base and base applications.

Compaction Characteristics

Figure 4 shows the moisture-density curves for the soil-RAP mixture treated with various amount of SCBA. The variation of maximum dry density, MDD and optimum moisture content, OMC with SCBA is shown in Figures 5 and 6, respectively. The MDD increased from 1.77 for the laterite soil to 1.79 Mg/m^3 for 60% soil/40% RAP mix and further increased to 1.82 Mg/m^3 with the addition of the SCBA up to 4%. Further addition of SCBA reduced the MDD. The initial increase in MDD may be due to the addition of RAP, which has a higher bulk density than the laterite soil.

The addition of RAP altered the particle size distribution of the soil. The arrangement of the soil/RAP mix is such that the fine particles of the soil fill the void space among the coarse particles of the RAP, which resulted in the formation of a denser matrix. This arrangement was further enhanced with the addition of SCBA of up to 4%. Further addition of the SCBA, however resulted in the decrease of the MDD of the mixture. This is due to the replacement of soil particles in a given volume with higher amount of SCBA of comparatively low specific gravity of 1.73. Other probable reason for the drop in MDD could be due to the product of cation exchange reaction between SCBA and the soil minerals, which will result in producing a flocculated and agglomerated clay particle structure. These particles occupy larger spaces that lead to a corresponding decrease in the dry density (Ola 1975). The OMC generally increased with addition of SCBA. This may be as a result of the increasing surface area of particles caused by the addition of SCBA. Thus there is a need for more water to lubricate the entire matrix of soil-RAP-SCBA mixture to enhance density. Also, as the amount of SCBA increased, more water is needed for pozzolanic reactions; therefore, OMC increased as the bagasse ash content increased because of extra water required for the pozzolanic reaction.

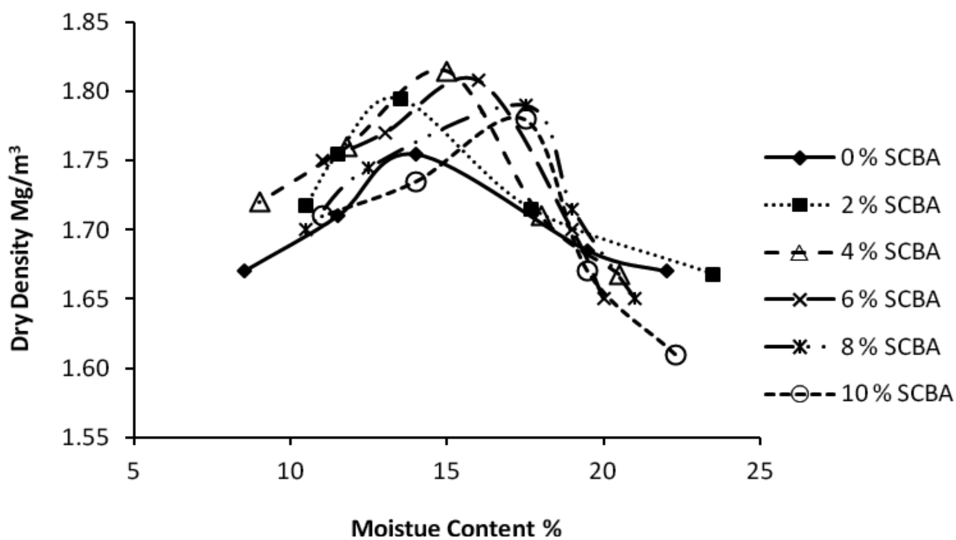


Fig. 4. Compaction curves showing dry density versus moisture content for each SCBA treatment

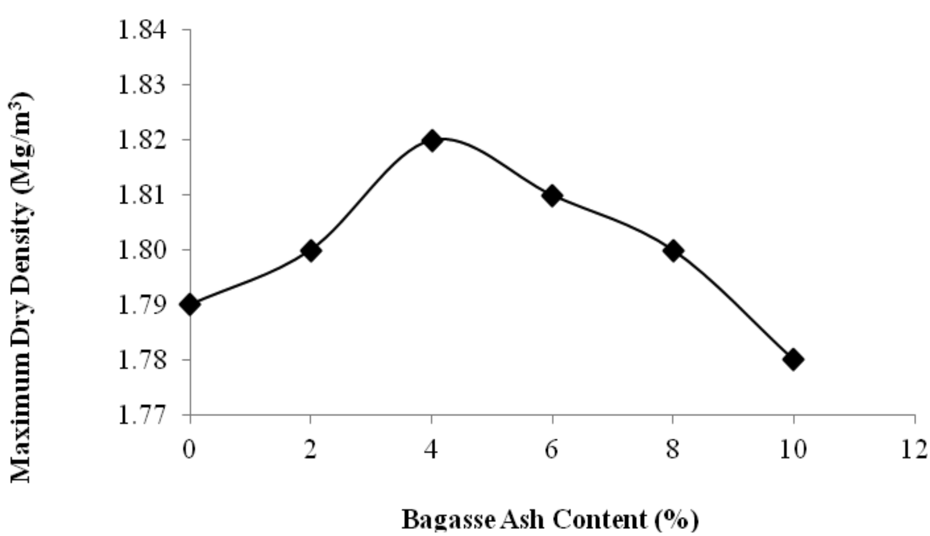


Fig. 5. Variation of MDD with bagasse ash (SCBA) treatment for soil-RAP mix

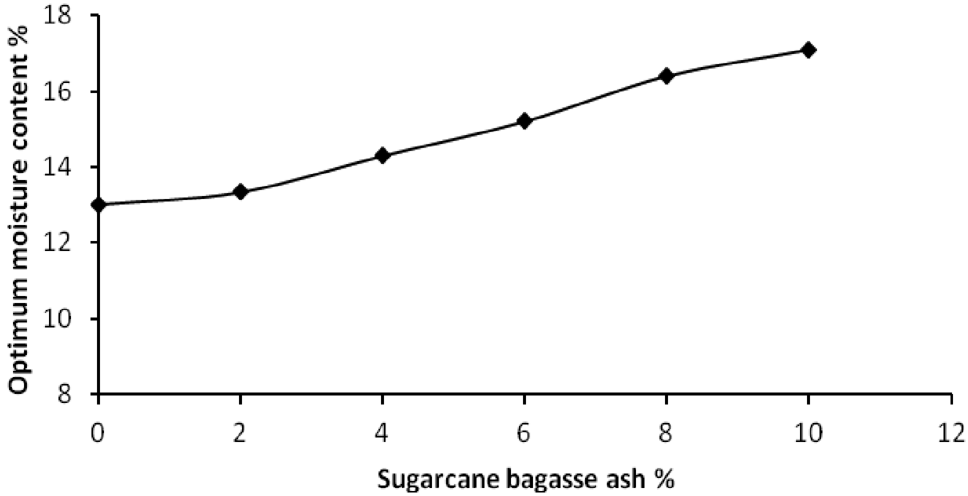


Fig. 6. Variation of OMC with bagasse ash (SCBA) treatment for soil-RAP mix

Unconfined compressive strength

Figure 7 shows the variation of unconfined compressive strength of the soil/RAP mix with SCBA treatment after 7 and 14 day curing periods. It is observed that the UCS increased with addition of SCBA. It is also observed that the UCS increased with the increase in curing period for all SCBA. This may be attributed to the pozzolanic reaction of SCBA, which resulted in a stronger soil-RAP-SCBA matrix, hence the increase in UCS. Pozzoloanic reactions are time dependent reactions, which result in strength development with time.

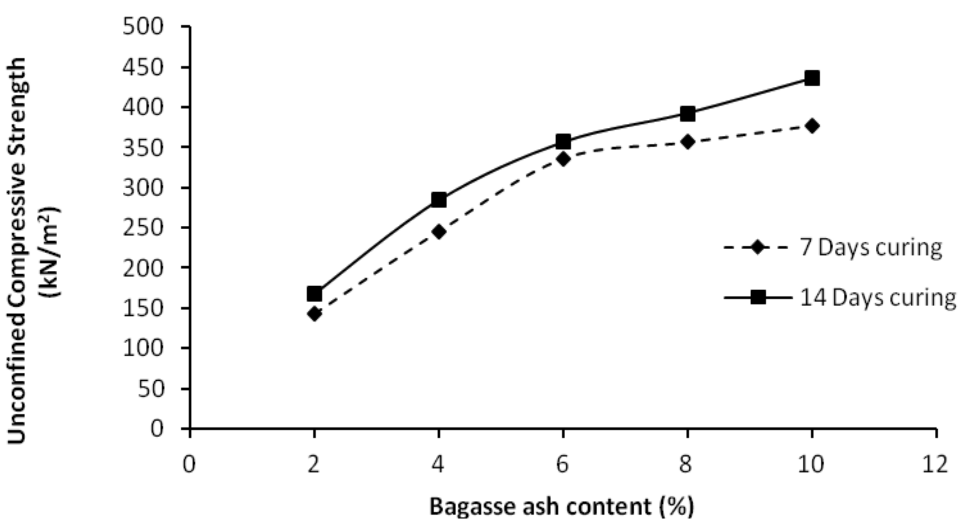


Fig. 7. Variation of UCS with bagasse ash (SCBA) treatment for soil-RAP mix

California bearing ratio

The California Bearing Ratio value of a soil is an important parameter used to indicate its strength and bearing capacity. It is widely used in design and to assess the suitability of soil materials (for base and sub-base course) in pavements.

The Nigerian general specifications (1997) recommend a CBR value of 180% be attained in the laboratory for cement stabilized material to be constructed by the mix-in-place method.

Gidigasu and Dogbey, (1980) as well as Gidigasu (1982) recommended minimum CBR values of 60 – 80 % for base course and 20 – 30 % for sub-base course, when specimen are compacted at optimum moisture content using the West African standard compactive effort. However, in this study, the recommended minimum conventional CBR values for lime-treated soils of 40, 80, and 100% (standard Proctor) for sub-base, base course (for lightly trafficked roads) and base course (for heavily trafficked roads), respectively, would be adopted in evaluating the strength of soil-RAP-SCBA mixture.

As shown in Figure 8, the CBR values increased as the SCBA content increased for both soaked and un-soaked specimens. A value of about 82 % was attained at 10 % SCBA content for the un-soaked sample. It can be seen from the results, which are shown in Figure 8 that at 6 and 8% SCBA content, the sub-base requirement is met and at 10 % SCBA, the base requirement is met for lightly trafficked roads.

The CBR value however declined after soaking for 24 hours for all SCBA treated samples. At 10% SCBA treatment, the CBR decreased to 40% representing about 48.7% reduction in strength. This is expected because as water penetrates the soil-RAP-SCBA mixture, it tends to break the bond formed by the soil minerals and the product of the pozzolanic reaction of SCBA, thereby reducing the strength of the specimen.

Based on the results observed and the strength criteria for soil-lime adopted in this study, 6 to 8% SCBA treatment of soil-RAP mixture yielded the best result for sub base course while 10% SCBA treatment of soil-RAP mixture gives the best result meeting the requirement of base course for light trafficked road.

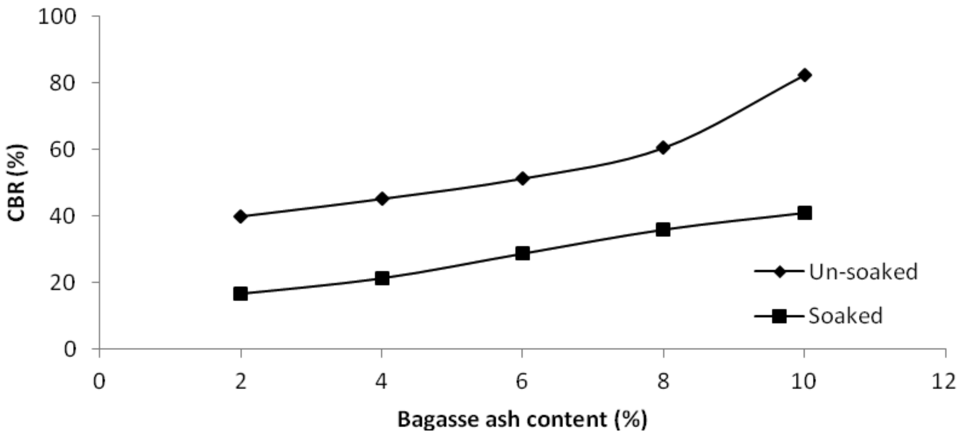


Fig. 8. Variation of CBR with bagasse ash (SCBA) treatment for soil-RAP mix

CONCLUSION AND RECOMMENDATION

From the results obtained in this study, it can be concluded that:

- Addition of RAP reduces the optimum moisture content and increases the MDD of the samples compared with the laterite soil while the addition of SCBA up to 4 % results in further increases in MDD; further addition of SCBA results in reduced MDD whereas OMC increased with increasing SCBA.
- UCS increased with higher SCBA proportions and longer curing periods.
- CBR increased with SCBA treatment with a peak value of 82 % at 10 % SCBA treatment for un-soaked specimen. This value however decreased to 40% after 24 hours soaking.

Based on the results observed and based on the strength criteria for soil-lime adopted in this study, treatment of soil-RAP mixture with 6 to 8% SCBA yielded the best result meeting the requirement of sub base course while treatment with up to 10% SCBA yielded result meeting the requirement of base course.

REFERENCES

Areola O., 1982. Soil in Nigeria Maps, Edition by Barhous K. M. Hodder and Stoughton London.

Decker, D. S. & Young, T. J., 1996. Handling RAP in an HMA Facility. Proceedings of the Canadian Technical Asphalt Association, Edmonton, Alberta.

Federal Ministry of Works, 1997. Nigerian General Specification on Road and Bridgeworks, Federal Government of Nigeria , Lagos, Nigeria.

Gidigasu, M. D. & Dogbey, J. L. K., 1980. Geotechnical characteristics of laterized ecomposed rocks for pavement construction in dry sub-humid environment. 6^{th} Southeast Asian conf. On soil engineering. 1: 493 – 506 Taipei.

Gidigasu, M. D., 1982. Importance of material selection, construction control and field performance studies in developing acceptance specification for lateritic paving gravels. Solos e Rochas*,* 5(1), Rio de Janeiro.

Hanks, A. J. & Magni. E. R., 1989. The Use of Bituminous and Concrete Material in Granular Base and Earth. Materials Information Report MI-137, Engineering Materials Office, Ontario Ministry of Transportation, Downsview, Ontario.

Ingles O. G., Metcalf J. A., 1972. Soil Stabilization principles and practice, Butter worth Sydney. 370 – 375.

Kallas, B. F., 1984. Flexible Pavement Mixture Design Using Reclaimed Asphalt Concrete, FHWA/RD-84/088.

Mohammedbhai, G. T. G & Baguant, B. K. 1985. Possibility of using Bagasse ash and other Furnance Residue as Partial Substitute for Cement in Mauritius. Revue Agricole et ucrlere de l'jje Maurice. 64 (3).

Nicholson, P. G., Kashyap, V. & Fuji, C. F., 1994. Lime and fly ash admixture improvement of tropical hawaiian soil. Transport Research Record. No. 1440. National Academy press, Washington D.C.

Ola, S.A., 1974. Need for estimated cement requirements for stabilizing lateritic soil. Journal of Transportation Engineering, ASCE, 17 (8): 379-388.

Ola S. A., 1975. Stabilization of Nigerian laterite soil with cement , bitumen and Lime Sixth Reg . Confab For Africa Soil Mechanic and Foundation on Engineering Durban South Africa, Sept. 145-152.

Osinubi, K. J., 1995. Lime modification of black cotton soil. Spectrum Journa*l* 2 (1 & 2): 112-122.

Osinubi, K. J. and Medubi, A., 1998. Evaluation of cement and phosphatic waste admixture on tropical black clay road foundation. Proc. Of the 4th Int. Conf. on Sructural Engineering Analysis and Modelling (SEAM 4*)*. Accra, 2: 297-307.

Osinubi, K. J., 1998b. Influence of compaction delay on the properties of cement- stabilised lateritic soil. Journal of Engineering Research, 6(1):13 - 26.

Osinubi K. J., 2000. Laboratory trial of soil stabilization using pulverized coal bottom ash. Nigerian Society of Engineers Technical Transaction, 35(4) 13-21.

Osinubi , K. J., 2001. Influence of compaction energy levels and delay on cement treated soils. The Nigerian Society of Engineers Technical Transactions. 36(4):13-21.

Rupnow,T. D., 2002. Subgrade stabilization using RAP and Fly Ash, Iowa State University, Midwest Transport Consortium.

Smith, Richard W., 1980. State-of-the-Art Hot Recycling. Transportation Research Board, Record No. 780, Proceedings of the National Seminar on Asphalt Pavement Recycling, Washington, DC.

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