International Journal of GEOMATE, Nov., 2019 Vol.17, Issue 63, pp. 360 - 370
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.63.86310
Geotechnique, Construction Materials and Environment

LABORATORY AND FIELD EVALUATION OF A-6 LATERITIC SOIL TREATED WITH RECLAIMED ASPHALT PAVEMENT AND ORDINARY PORTLAND CEMENT

*Mustapha Mohammed Alhaji[1], Musa Alhassan[2], Taiye Waheed Adejumo[3] and Awwal Tanko Umar[4]

[1,2,3,4] Department of Civil Engineering, Federal University of Technology, Minna, Nigeria

*Corresponding Author, Received: 14 April 2019, Revised:10 May, Accepted: 8 June 2019

ABSTRACT: An A-6 lateritic soil was stabilized with Reclaimed Asphalt Pavement and 2% cement. The lateritic soil was mixed with 0, 20 to 140% RAP and each mixture compacted in the laboratory. The soil mixed with120% RAP gave the highest Maximum Dry Density of 2.252Mg/cm^3. Laboratory California Bearing Ratio test was conducted on the soil, soil/120% RAP and soil/120% RAP/2% cement. A 15m section of untarred road was identified and demarcated into three sections (A, B and C) of 5.0m each. Materials on section A of the road composed of the lateritic soil/120% RAP/2% cement, section B contains lateritic soil/120% RAP, while section C composed of the lateritic soil only. The sections were compacted using smooth drum vibratory roller. In-situ density test and CBR test using Dynamic Cone Penetration test were carried out on the three sections of the road after 1, 7, 14, 28, 60 and 90days. The laboratory densities of materials used for the three sections are 2.254, 2.252 and 2.154g/cm^3, while in-situ densities after 60 days were 2.249, 2.225 and 2.142Mg/cm^3 for sections A, B and C respectively. The laboratory CBR values after 60 days were 118, 37 and 22%, while the field CBR values were 44.5, 49.0 and 112% for sections A, B and C respectively. It was concluded that in-situ and laboratory densities and CBR values closely agreed. However, the maximum densities were observed after 60days of field compaction. Also, only 90% of in-situ dry density was achieved immediately after the field compaction.

Keywords: A-6 Lateritic Soil, California Bearing Ratio, Compaction, Dynamic cone penetration, Ordinary Portland cement, Reclaimed asphalt pavement, Stabilization

1. INTRODUCTION

Lateritic soils have been used extensively as sub-grade and sub-base courses for low trafficked roads in Nigeria and some other countries where their deposit exists. However, most of these soils have also been observed to fall short of the standard specifications for them to be used as base course material for road structure [1, 2]. One of the classes of lateritic soil that have always fall short of the standard, is A-6 class, according to the American Association of State Highway and Transportation Officers (AASHTO) standard [3]. These deficiencies have been observed to have always resulted from the nature and composition of clay contained in the soil [4-6]. These deficient lateritic soils require stabilization to improve their strength and durability [7, 8].

Reclaimed Asphalt Pavement (RAP) is aged asphalt, removed from road surfaces during maintenance or rehabilitation of roads. These materials usually constitute a waste in Nigeria and some other West African countries due to the limited technology of recycling the asphalt. The use of RAP mixed with a little amount of bitumen and other related admixtures to reconstitute fresh asphalt for road surfacing were studied by some researchers [9-13]. These authors, whose work are mostly laboratory based with little field experimentation, recorded success at various levels. The potential of RAP to improve the engineering properties of soils with or without admixtures for road base and sub-base have been studied by some researchers [3, 14-21]. But most of these studies were done at the laboratory level.

The use of Dynamic Cone Penetration test to indirectly evaluate the strength of subgrade, sub-base and base courses have been a subject of study for more than two decades [22-30]. Dynamic cone penetration test has been used for the design of pavement structure [31, 32], to check the degree of compaction during and after compaction [33, 34] and to estimate the standard life of the pavement structure [35]. This method of evaluating the strength of in-situ compacted surfaces have been found to be simple, more accurate and more reproducible because of the difficulty in collecting an in-situ sample for California Bearing Ratio (CBR) test in the laboratory.

The aim of this study, therefore, is to evaluate the laboratory and field densities and strength of 120% RAP/laterite/2% cement, 120% RAP/laterite and laterite only and to compare the laboratory result with field results. The field studies were based on section A containing optimal mixture of A-6 lateritic soil and RAP admixed with 2%

Portland cement, section B containing an optimal mixture of A-6 lateritic soil and RAP only, while section C contains A-6 lateritic soil only.

1.1 Use of Reclaimed Asphalt Pavement in Road Structure

Aside from the numerous studies on the use of RAP in asphalt for road surfacing, a lot more work has been carried out on the use of RAP, either fully or as a replacement, with or without admixture, to stabilized subgrade, sub-base and base courses in road structure. Beeghly [36] express his experience when a mixture of lime and fly ash was used to stabilize a pavement subgrade soil. The author concluded that the strength gain was sufficient for a stable subgrade. Mohammad [19] also used laboratory and field experiment to investigate the potential use of foamed asphalt treated RAP as a base course material instead of a crushed limestone base. The author highlighted major factors that affect foamed asphalt to include the amount of fines, asphalt content and optimum moisture content, and therefore recommended 1.5% minimum asphalt content for this type of asphalt. The optimum moisture content was observed to be the water content at which the soil aggregate has its maximum bulk volume. It was concluded that foam asphalt showed higher in-situ stiffness values and structure numbers than the use of limestone base.

Gregory and Halsted [37] worked on Full Depth Reclamation (FDR) of RAP to form a new base. This study attempted to mix the aged asphalt surface with the in-situ existing base and possibly, sub-base material with a small amount of cement which is compacted to form an excellent base course. It was observed that a cement content that will provide a 7days unconfined compressive strength of between 2.1 to 2.8MPa is satisfactory for FDR applications. According to the author, other stabilizing additives used for FDR are asphalt emulsion, cement, foamed asphalt and lime/fly ash. Edeh *et al*., [38] worked on the stabilization of lateritic soil using RAP and 2% cement as flexible highway pavement materials. The specific gravity of the 100% RAP used by the author was 2.25. It was concluded that the CBR values obtained increased from 17.9 to 55.0% which implies that the stabilized material can be used for subgrade and sub-base courses in road structure based on Nigerian General Specification for Roads and Bridge Works [39].

Edeh *et al*., [40] stabilized clay with lime and RAP for use as highway pavement materials. The Maximum Dry Density (MDD) of 100% RAP and clay were 2.03 and 1.64gcm^3 respectively, while Optimum Moisture Content (OMC) of the 100% RAP and clay were 15.01 and 21.02% respectively. The CBR values of 100% RAP was observed to be 16 and 32% for soaked and unsoaked tests. The authors concluded that 90% Rap + 4% clay + 6% lime has CBR of 36.6%, while 90% RAP + 2% clay + 8% lime resulted in a CBR of 34.23%, both of which can be used as subgrade and sub-base for road structure based on Nigerian Standard [39].

A study aimed at increasing the strength and reducing creep of RAP by adding high-quality aggregate and or adding chemical stabilizer was carried out by Bleakley and Cosentino [41]. LBR test was used by the author to evaluate the strength of the mixture while the creep test was used to evaluate the properties of creep. There was an increase in LBR from 142 at 50% RAP/50% LR to 284 at 25% RAP/75% LR. Blends of 75% RAP did not reach unsoak LBR of 100%.

Ochepo [42] stabilized lateritic soil using RAP and Sugarcane Bagasse Ash (SCBA) for pavement construction. The lateritic soil stabilized classified as A-7-6 and CL based on the AASHTO and Unified Soil Classifications System (USCS) respectively. The MDD of the mixture increased from 1.77 to 1.79Mg/m^3 for 60% soil/40% RAP, which further increased to 1.82Mg/m^3 with an addition of 4% SCBA. Increase in SCBA beyond this value reduces the MDD. Both UCS and OMC increase with an increase in SCBA. The author observed that the lateritic soil stabilized with 6 and 8% SCBA gave CBR sufficient for the mixture to be used as subgrade and sub-base courses, while the mixture treated with 10% SCBA gave CBR that is sufficient for the mixture to be used as a base course material.

Mustapha *et al*., [3] worked on possible stabilization of A-6 lateritic soil using RAP without any chemical admixture. The A-6 lateritic soil was replaced with RAP at 0:100, 10:90 to 100:0. It was observed that the optimum mixture of 60:40 gave the highest MDD and was used as the basis on which other tests were carried out. The MDD was observed to increase from 1.895Mg/m^3 at 100:0 to its maximum value of 2.170Mg/m^3 at 40:60, after which the values reduced to 2.017Mg/m^3 at 0:100. The UCS was observed to have minimal increase from 346kNm^2 for the natural A-6 lateritic soil to 384kN/m^2 at 40:60 mixtures, while the CBR increased marginally from 45.1% for natural lateritic soil to 48.6% at 40:60 mixtures.

Mishra [43] study the use of RAP material in flexible pavements in which typical values of unit weight, natural moisture content, asphalt content, compaction densities and CBR values were reported. The typical values are 1900-2250kg/m3 for the density, 3-5% for the natural moisture content, 5-6% for asphalt content, 1500-1950kg/m3 for the compacted unit weight and 20-25% for CBR of 100% RAP. The author used 50% RAP replacement for granular sub-base and concluded that 30% replacement of natural aggregate by RAP can successfully be used in the base course.

The suitability of RAP as sub-base using factorial experiments was studied by Kamel *et al*., [44]. The RAP ratios used are 0%, 10%, 50%, 90% and 100% mixed with subgrade soil and the test criteria used to evaluate strength are UCS and CBR. Extraction test on the RAP gave 5.09% bitumen. MDD was observed to increase from 2.155t/m3 at 0% RAP-100% soil to 2.212t/m3 at 100% RAP-0% soil. The OMC, on the other hand, reduced from 5.8% at 0% RAP-100% soil to 4.6% at 100% RAP-0% soil. The author reported increase in CBR values of 43% at 0% RAP-100% soil to 59% at 50% RAP-50% soil after which the value reduced to 22% at 100% RAP-0% soil. The UCS values decreased from 321kN/m2 at 0% RAP-100% soil to 55kN/m2 at 100% RAP-0% soil.

The use of geopolymer materials to stabilize RAP for base courses was carried out by Avirneni *et al*., [45]. This technology involves alkaline treatment of pozzolanic materials to form a highly alkaline medium (pH>12). The author observed that fly-ash stabilization alone could not impact sufficient strength on the RAP-VA mixtures. However, activation of fly-ash with 2% and 4% sodium hydroxide was observed to enhance the strength gain of the mixture to UCS greater than the design strength of 4.5Mpa. The durability was also observed to perform satisfactorily. Horpibulsuk *et al*., [16] also used the same technology for sustainable stabilization of RAP for sub-base. It was concluded that 7 days UCS of the compacted RAP-FA blend at OMC meets the strength requirement for the base course specified by national road authority. Alhaji and Alhassan [14] worked on the microstructure and strength of RAP stabilized clay for road structure. The clay studied classified under clay of high plasticity (CH) based on the unified soil classification system, while the bitumen content of the RAP was 5.99%. The MDD increased from 1.890Mg/m3 at 0% RAP-100% clay to maximum of 2.036Mg/m3 at 30% RAP-70% clay after which the values reduced to 1.925Mg/m3 at 100% RAP-0% clay. The OMC reduced from 13.7% at 0% RAP-100% clay to 8.0% at 100% RAP-0% clay. The CBR results increased from 11% at 0% RAP-100% clay to 35% at 30% RAP-70% clay after which the values reduced to 5% at 100% RAP- 0% clay.

1.2 Dynamic Cone Penetration Test for Pavement Strength Evaluation

The uses of the DCP test to evaluate the strength of pavement structure through penetration index have been under study for a few decades. This method of evaluating the strength of in-situ pavement structure through penetration index, have been observed to give accurate and reproducible results when compared to laboratory results.

Siekmeier *et al.,* [23] compared DCP with other tests during subgrade and granular base characterization in Minnesota. The author observed that the existing empirical method of quality assurance testing of subgrade and base materials which are based on soil classification, grading, moisture control, lift thickness limits and compaction testing, does not work well for mechanistic-empirical methods of design. The quality assurance testing for mechanistic-empirical design would include in-situ shear strength test using the DCP test. The DCP index for each drop was used to calculate the CBR using the expression

$$CBR(\%) = \frac{292}{DPI^{1.12}} \tag{1}$$

For CBR > 10% and

$$CBR(\%) = \frac{1}{(0.017019 * DPI)^2} \tag{2}$$

For CBR < 10%

The resulting CBR were then used to evaluate the modulus of elasticity from the expression

$$E(MPa) = 17.6 * CBR^{0.64} \tag{3}$$

Nguyen and Mohajerani [46] worked on the effect of vertical confinement from CBR mold on the DCP index. It was observed that the effect of vertical confinement is very significant especially with hammer mass greater than 4.6kg, but is not significant if the hammer mass is less than 2kg. The author, therefore, developed a new light weight DCP with a hammer mass of 2.25kg which can be used both in the laboratory and in the field with similar results.

Comparative study of subgrade soil strength estimation models developed based on CBR, DCP and Falling Weight Deflectometer (FWD) test results were studied [47]. Regression models were developed to give the relationship between CBR and DCP as well as between modulus of elasticity and DCP. Similarly, Singh *et al.*, [21] worked on the evaluation of soil subgrade using In-situ tests. DCP and FDW were used to determine the strength of compacted surfaces at different locations. The results obtained were used to correlate DCP with other parameters.

Study on the modeling of a light dynamic cone penetration test–Panda 3(R) in granular materials by using 3D discrete element method was carried out by Tran *et al.,* [48]. Light dynamic penetration test–Panda 3(R) provided dynamic load-penetration curves for each blow. This curve was influenced by the mechanical and physical properties of the granular medium. It was possible to use force and acceleration measured in the top part of the rod, separate the incident and reflected waves and calculates the tips load-penetration curve.

2. TEST LOCATION

The laboratory aspect of this study was carried out in Civil Engineering laboratory of Federal University of Technology, Minna, Niger State, Nigeria. The In-situ (field) test was carried out on an access road between Central Workshop and Civil Engineering laboratory of Federal University of Technology Minna, leading to Agricultural Engineering workshop. The first 200m of the road has earlier been constructed and paved with concrete surfacing by Student Work Experience Programme (SWEP). The remaining 500m has been left unconstructed and have continued to undergo serious erosion.

3. METHOD OF EXPERIMENTATION

3.1 Laboratory Tests

A substantial amount of the lateritic soil was collected from a borrow pit at Gidan Kwanu village of Niger State, using trucks and placed close to the test location (Fig. 1). A substantial amount of milled RAP (Fig. 2) was also collected from a failed road, at Kwakuti, along Minna-Suleja road.

Fig. 1: Pile of lateritic soil

Fig. 2: Pile of milled RAP

These materials were manually mixed to allow for uniformity in the samples to be tested. Samples were taken from each of the stockpiled materials and carried to Civil Engineering laboratory for tests, which includes grain size analysis, Atterberg limits, modified Proctor compaction test and California Bearing Ratio tests. To obtain compaction characteristics of the mixtures, compaction tests (Fig. 3) were carried out on the soil and the soil mixed with 0, 20, 40, 50, 60, 80, 100, 120 and 140% RAP by weight of the soil. This was to determine the mixture that will give the highest MDD and the subsequent OMC. CBR test (Fig. 4) was carried out on the mixture that gave the highest MDD and another of the mixture containing 2% cement.

Fig. 3: Compaction test

Fig. 4: Compacted samples for CBR test

3.2 Field Tests

The field aspect of this study was carried out on a section of the road whose width was 8.0m and 15.0m length. The 15.0m length was divided into three sections of 5.0m each. The first section, which was following the already concrete paved part of the road, was filled with a mixture of RAP, lateritic soil and 2% cement. The second section was filled with the obtained optimum mixture of RAP/lateritic soil mixture, while the third section was filled with the lateritic soil only. Figure 5 shows a sketch of test sections of the road and the test points.

The existing road surface was cleared of organic substances. The leveling of the road surface was taken using theodolite (Fig. 6) and a standard slope ensured. The surface was then pegged with lines and the sections demarcated using wooden planks (Fig. 7) to avoid soil from one section mixing with that in the other during placement and compaction. After forming and preparation of the sections, the mixtures for each of the sections were constituted and placed to 30cm lift manually. A 27 tons vibratory roller was used to roll and compact the material for 15 drives after which another 30cm lift of the material was placed on top of the initial layer and rolled in the same manner (Figs. 8 and 9).

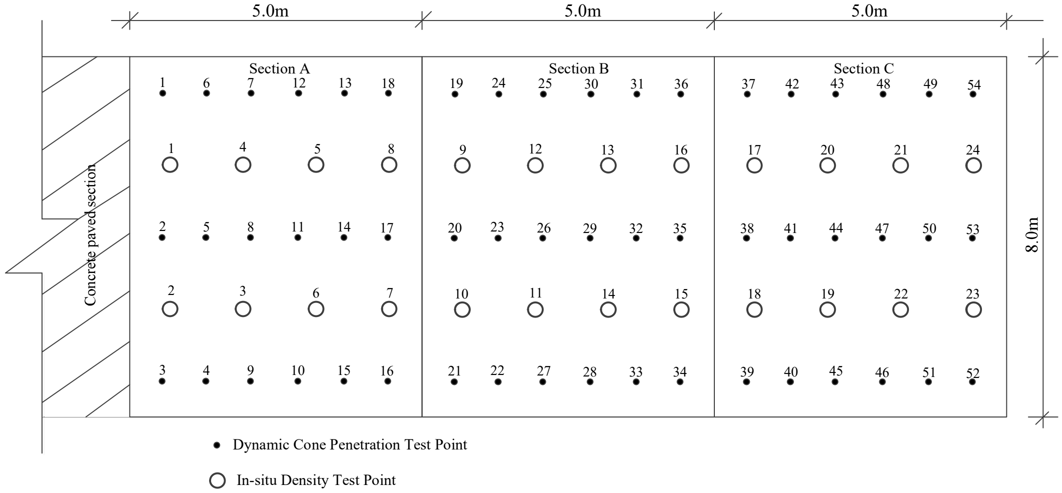

Fig. 5: Schematic diagram of the tested section of the road showing the tested points

Fig. 6: Theodolite for leveling of subgrade

Fig. 8: Field compaction in progress

Fig. 7: Sections demarcated with planks

Fig. 9: Boundary with the existing pavement

In-situ density test (Fig. 10), using a sand replacement method was carried out on the compacted surfaces after every 10 drives to determine the maximum in-situ density which became constant with further drives. Average of three in-situ densities was performed after 1, 28, 60 and 90 days of compaction. Dynamic Cone Penetration (DCP) tests (Fig. 11) were also conducted at three positions after 1, 7, 14, 28, 60 and 90 days of compaction.

Fig. 10: In-situ density test on the road surface

Fig. 11: DCP Test on a compacted surface

4. RESULTS AND DISCUSSION

4.1 Index Properties of RAP and Lateritic Soil

Results of index properties of the lateritic soil and the RAP are presented in Table 1. From Table 1, the lateritic soil classified as A-6 soil according to AASHTO soil classification system and clay of low plasticity according to USCS.

Table 1: Summary of physical properties of lateritic soil and Reclaimed Asphalt Pavement

Description	Lateritic soil	Reclaimed Asphalt Pavement
Liquid Limit (%)	39.4	NP
Plasticity Index (%)	24.4	NP
Percentage passing sieve 5.00mm (%)	85.9	42.7
Percentage passing sieve 2.00mm (%)	75.7	27.2
Percentage passing sieve 0.425mm (%)	64.9	9.9
Percentage passing sieve 0.075mm (%)	48.0	00
Specific gravity	2.63	2.40
Maximum dry density (BSH)	2.15	2.22
Optimum moisture content (BSH)	11.3	7.6
AASHTO classification system	A-6	A-1-a
Unified Soil Classification system	CL	GP

This soil, according to Nigeria General Specification for Roads and Bridge Works [39], cannot be used as sub-base and base courses for road pavement structures and will, therefore, require stabilization to improve its strength and durability. The RAP classified as A-1-a according to AASHTO soil classification system and poorly graded gravel according to USCS. This material, when mixed with the A-6 lateritic soil can positively improve the grading of the mixture and hence increase its engineering properties.

4.2 Laboratory and Field Densities

4.2.1 Laboratory densities

Laboratory density was determined from laboratory compaction test conducted at the modified compaction energy level. The compaction was carried out on the soil mixed with 0, 20, 40, 50, 60, 80, 100, 120 and 140% RAP by weight of the dry soil. Variations of MDD and OMC with a change in RAP composition are presented on Figs. 12 and 13 respectively. The trend shows an increase in MDD from 2.154Mg/cm^3 at 0% RAP content to its maximum of 2.252Mg/cm^3 at 120% RAP after which the values decreased. This trend is in agreement with Mustapha *et al*., [3] and Alhaji and Alhassan [14]. Increase in percentage RAP improves the grading of the soil which increases the density of the mixture. This process continued until all the pores of the RAP were completely filled up with the soil. Increase in RAP beyond this point resulted in the creation of new pore spaces, which eventually reduced the density of the mixture. MDD of the soil, mixed with 120% RAP and 2% cement

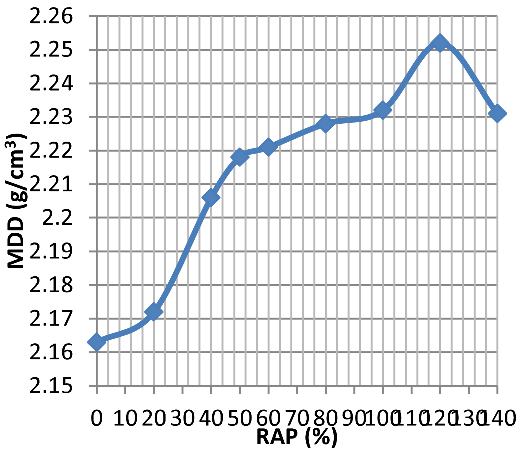

Fig. 12: Variation of MDD with RAP content

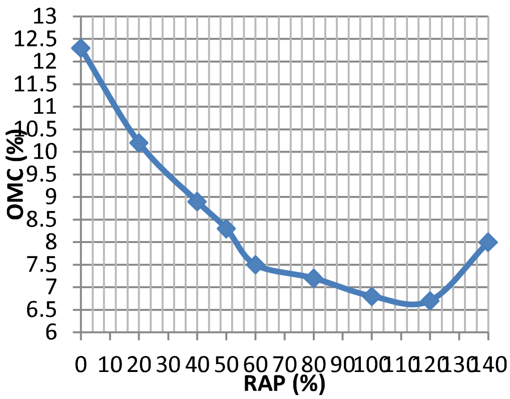

Fig. 13: Variation of OMC with RAP content

The trend of variation of OMC with an increase in percentage RAP showed a decrease in OMC from 11.4% at 0% RAP to a minimum of 6.7% at 120% RAP, after which the values increased to 8.0% at 140% RAP. This trend is also in agreement with Alhaji and Alhassan [14] who attributed this trend to reduction in OMC due to a reduction in the lateritic soil containing a substantial amount of fines and increase in RAP which has little or no affinity for water absorption. The excess pores generated by excess RAP in the soil-RAP mixture also tend to retain water, which contributed to the sudden increase in moisture content beyond the optimal position.

4.2.2 Field densities

The field densities were determined using a sand replacement method as highlighted in BS 1377 [49]. This test was conducted continuously on the three compacted surfaces of the road during compaction until three consecutive trials gave very close results. This was repeated after 1, 28 days 60 days and 90 days and the results are presented on (Table 2).

From Table 2, it was observed that the dry densities for section C do not vary significantly throughout the 90 days of the study. However, the. dry densities for sections A and B increased with days to its maximum at 60 days. Beyond 60 days, the dry densities reduced slightly. More so, the achieved maximum dry densities in sections A and B after 60 days was 99.8 and 98.8% respectively.

Table 2: Summary of the In-situ densities for the three sections of the road

Sections of the Road	1 day	28 days	60 days	90 days
Section A	2.001	2.182	2.194	2.183
	1.937	2.184	2.256	2.264
	2.147	2.196	2.296	2.288
Average density (Mg/cm^3)	2.028	2.187	2.249	2.245
Section B	2.005	2.152	2.230	2.211
	2.037	2.186	2.226	2.214
	2.086	2.108	2.218	2.230
Average density (Mg/cm^3)	2.043	2.149	2.225	2.218
Section C	2.149	2.131	2.134	2.128
	2.144	2.141	2.140	2.134
	2.123	2.152	2.153	2.161
Average density (Mg/cm^3)	2.139	2.142	2.142	2.141

The dry densities recorded in sections A and B a day after roller compactions were observed to be 90% and 90.7% respectively. The high level of consistency, observed in section C was attributed to the fact that the materials do not contain RAP, but rather a clay which aided instant compaction.

Compaction of sections A and B to its laboratory density cannot be achieved immediately on completion of roller compaction but can be achieved gradually after a period of between 1 to 2 months, depending on the traffics on the road.

4.3 Laboratory and Field CBR values

4.3.1 Laboratory CBR

Laboratory CBR was conducted based on the method highlighted in BS 1377 [49]. The test was conducted on the A-6 lateritic soil, a mixture of laterite and 120% RAP and mixture of the soil, 120% RAP and 2% cement. The soil/120% RAP/2% cement mixture was cured for 7 days before the test. Summary of the CBR values for top and bottom, as well as the average is shown on Table 3. Based on CBR criteria, highlighted in Nigerian General Specification for Roads and Bridge Works [39], The A-6 lateritic soil can only be used as subgrade material, mixture of soil/120% RAP can only be used as sub-base material, while the soil/120% RAP/2% cement can be used both as sub-base and base course material.

Table 3: summary of laboratory CBR values

Type of soil mixture	Top		Bottom
A-6 Lateritic soil only	18.0		26.0
Average CBR (%)		22.0	
Mixture of A-6 laterite and 120% RAP	32.0		42.0
Average CBR (%)		37.0	
Mixture of laterite, 120% RAP and 2% cement	100.0		136.0
Average CBR (%)		118.0	

4.3.2 Field CBR

The field CBR was evaluated using the DCP test on the compacted surfaces with the aid of an empirical relationship developed by TRL [50].

$$\boldsymbol{Log\ (CBR) = 2.48 - 1.057 Log(PI)} \quad (1)$$

Where PI, is the penetration index.

Summary of the field CBR values is given in Table 4.

Table 4: Summary of the average number of blows for the 20cm thick compacted surface at a varied number of days

Sections of the Road	1 day	7 days	14 days	28 days	60 days	90 days
Section A	28	43	53	65	76	77
	33	44	51	66	78	77
	31	45	53	68	81	82
Average number of blows	30.7	44.0	52.3	66.3	78.3	78.7
Section B	27	29	32	36	36	35
	30	27	32	37	37	38
	26	30	33	35	36	36
Average number of blows	27.7	28.7	32.3	36.0	36.3	36.3
Section C	25	27	30	33	32	31
	25	26	31	33	33	33
	23	24	30	33	35	34
Average number of bows	24.3	25.7	30.3	33.0	33.3	32.7

Averages of the number of blows were used to obtain penetration index which was used in equation 1 to evaluate the CBR values. Figure 14 shows the variation of the CBR values with days for the three (A, B and C) sections of the road. CBR in section B increases marginally from 41.8% after 1 day of compaction to 49.3% after 28 days, after which the values became almost constant at 49.4% after 90 days.

This trend is similar to section C, whose CBR was 36.7% after 1 day of compaction and increases marginally to 45% after 28days. The values remain relatively constant at 44.5% after 90 days. The marginal increases observed are probably due to low traffic loads from vehicle movements to and from the respective offices situated along the road under study. Section A, whose material contained Portland cement shows a tremendous increase in CBR from 60.5% after one day of compaction to a maximum of the value of 112.1% after 60 days. Relatively constant CBR value of 112.6%

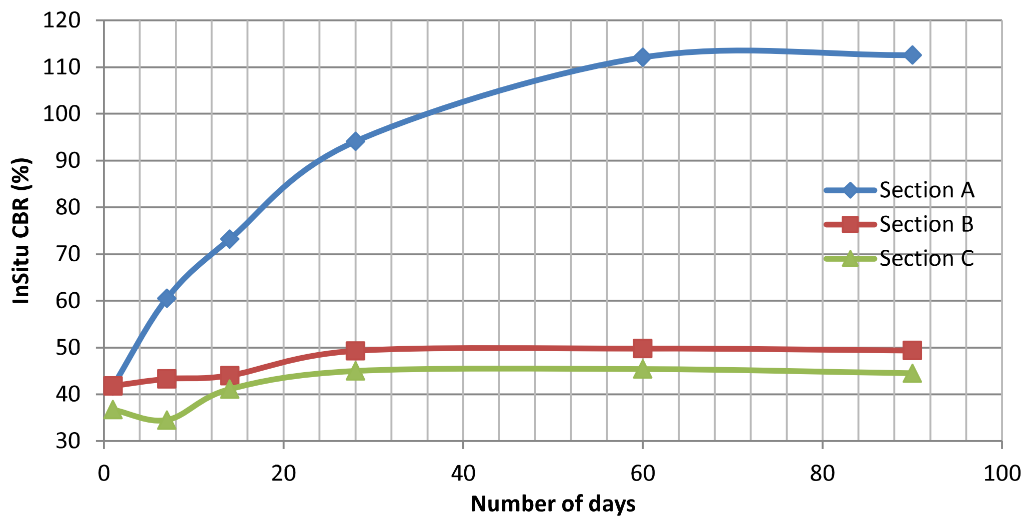

Fig. 14: Variation of In-Situ CBR values with the number of days

was observed after 90 days. This increase is attributed to the hydration reaction of cement, coupled with the enhanced gradation of the mixture. Contribution of traffic load also aid continuous densification of the compacted surface.

5. CONCLUSION

From the study, the following conclusions were drawn:

1. The lateritic soil classified under A-6 soil, while the RAP classified under A-1-a soil according to AASHTO soil classification system.
2. 120% RAP by weight of the lateritic soil was observed to give optimal dry density for a mixture of the A-6 lateritic soil and RAP.
3. Field results of compacted 120% RAP/laterite/2% cement mixtures used in sections A and 120% RAP/laterite used in section B agreed closely with the laboratory results after 28 to 60 days of roller compaction.
4. The field result of the lateritic soil used in section C was observed to be higher than the laboratory results. This confirms that the dynamic cone penetration test overestimates the strength of clay soils.
5. From field density and laboratory density results for the optimal mixture of A-6 lateritic soil and RAP, it was observed that only about 90% in-situ dry density can be achieved immediately after the roller compaction. The density will increase towards laboratory value after 28 days of roller compaction
6. It is suggested as a future work for a similar study to be carried out using Portland cement and a pozollana for prolong development in strength.

6. REFERENCES

[1] Aginam, C. H., Chidolue, C. A. and Nwakaire, C., Geotechnical Properties of Lateritic Soils from Northern Zone of Anambra State, Nigeria. International Journal of Engineering Research and Development, Vol. 10, Issue 12, 2014, pp 23-29.

[2] Oghenero, A. E., Okey, A. T., Brume, O., Okunuwadje, S. E. and Jerry, O., Classification and Compaction Characteristics of Lateritic Soils of Warri, Delta State, Nigeria, Advances in Applied Sciences Research, Vol. 5, Issue 3, 2014, pp 451-457.

[3] Mustapha, M. A., Jibrin, R. Etsuworo, N. M. and Alhassan, M. Stabilization of A-6 Lateritic Soil using Cold Reclaimed Asphalt Pavement. International Journal of Engineering and Technology, Center for Professional Research, UK, vol. 4(1), 2014, pp. 52–57.

[4] Adebisi, N. O., Adeyemi, G. O., Oluwafemi, O. S. and Songca, S. P., Important Properties of Clay Content of Lateritic Soils for Engineering Projects. Journal of Geography and Geology, Vol. 5, No. 2, 2013, pp 99-115.

[5] Otoko, G. R., Dependence of Shear Strength and Compressibility of Tropical Lateritic Soils on Clay Content. International Journal of Engineering and Technology Research, Vol. 2, No. 2, 2014, pp 1-9.

[6] Okunlola, I. A., Amadi, A. N., Dindey, A. O. and Kolawole, L. L., Geotechnical and Geochemical Properties of Lateritic Profile on Migmatite –Gneiss along Ogbomosho-Ilorin Highway, Southern Nigeria. Civil and Environmental Research, Vol. 7, Issue 4, 2015, Pp 79-85.

[7] K. J. Osinubi and A. M. Mustapha. Optimal use of Bagasse Ash on Cement Stabilized Laterite. NSE Technical Transactions, Vol. 44, issue 1, 2009, pp. 1-16.
[8] Zumrawi, M. M. E., Prediction of In-situ CBR of Subgrade Cohesive Soils from Dynamic Cone Penetrometer and Soil Properties. International Journal of Engineering and Technology, Vol. 6, Issue 5, 2014, pp 439-442.
[9] Al-Rousan, T., Asi, I., Al-Hattamleh, O. and Al-Qablan, H. Performance of Asphalt Mixes Containing RAP. Jordan Journal of Civil Engineering, Vol. 12, No. 3, 2008, Pp 218-227.
[10] Al-Qadi, Q. N., Al-Qadi, A. N. and Khedaywi, T. S., Effect of Oil Shale Ash on Static Creep Performance of Asphalt Paving Mixtures. Jordan Journal of Earth and Environmental Sciences, Vol. 6, No. 2, 2014, Pp 67-75
[11] Pradyumna, T. A., Mittal, A. and Jain, P. K., Characterization of Reclaimed Asphalt Pavement (RAP) for use in Bitumenous Road Construction. 2nd International Conference of Transportation Research Group of India, Vol. 104, 2013, Pp 1149-1157
[12] Varamini, S., Ambaiowei, D., Sanchez, X., and Tighe, S. L., Evaluation of Asphalt Binder Characteristics of Typical Ontario Superpave CRM and RAP-HMA Mixtures, 2014.
[13] Akbulut, H. and Gurer, C., Use of Aggregate from Marble Quarry Waste in Asphalt Pavements. Building and Environment, Vol. 42, 2007, pp 1921-1930.
[14] Alhaji, M. M., and Alhassan M., Effect of Reclaimed Asphalt Pavement Stabilization on the Microstructure and Strength of Black Cotton Soil. International Journal of Technology, Vol. 9, Issue 4, 2018, pp. 727-736.
[15] Plati, C. and Cliatt, B., A Sustainability Perspective for Unbound Reclaimed Asphalt Pavement (RAP) as a Pavement Base Material. Sustainability, Vol. 11, Issue 78, 2018, pp. 1-17.
[16] Horpibulsuk S., Hoy M., Witchayaphong P., Rachan R., Aruliajah A., Recycled Asphalt Pavement – Fly ash Geopolymer as a Sustainable Stabilized Pavement Material. INCITE 2017 Conference in Material Science and Engineering, Vol. 273, 2017, pp 1-11.
[17] Sultan, S. A. and Guo, Z., Evaluating the Performance of Sustainable Perpetual Pavements Using Recycled Asphalt Pavement in China. International Journal of Transportation Science and Technology, Vol. 5, 2016, pp 200-209.
[18] Abukhettala, M. Use of Recycled Materials in Road Construction, Proceedings of the 2nd International Conference on Civil, Structural and Transportation Engineering, Ottawa, Canada, 2016, pp 138-1 – 138-8.
[19] Mohammad, L. N., Abu-Farsakh, M. Y., Wu, Z., and Abadie, C., Louisiana Experience with Foamed Recycled asphalt pavement Base Materials. 82nd Transport Research Board Annual Meeting, 2003, pp 1-19.
[20] Halsted, G. E., Using Cement to Reclaim Asphalt Pavement. Annual Conference of Transportation Association of Canada, Seskatoon, Saskatchewan, 2007, pp. 1-20.
[21] Singh D., Jha J. N. and Gill K. S., Strength Evaluation of Soil Subgrade Using In-situ Tests. Civil Engineering and Architecture, Vol. 4, Issue 6, 2016, pp. 201-212.
[22] Muhammed J. J., and Abdella M. M., Evaluation of Subgrade Capacity of Jimma Soils Using Dynamic Cone Penetration Test: A Correlation of CBR and DCPI. Malaysian Journal of Civil Engineering, Vol. 30, Issue 3, 2018, pp 457-467.
[23] Sickmeier, J. A., Young, D. and Beberg, D. Comparison of the Dynamic Cone Penetrometer with other tests during Subgrade and Granular Base Characterization in Minnesota, NonDistructive Testing of Pavement and Back Calculation of Moduli, Third Volume, ASTM STP 1375, 1999.
[24] Chukka, D. and Chakravarthi, V. K., Evaluation of Properties of Soil Subgrade Using Dynamic Cone Penetration Index-A Case Study. International Journal of Engineering Research and Development, Vol. 4, Issue 4, 2012, pp. 7-15.
[25] Hussein A. A. and Alshkane Y. M. Prediction of CBR and Resilient Modulus of Fine-Grained Soils Using Dynamic Cone Penetration Test Index. 4th International Engineering Conference on Developments in Civil and Computer Engineering Applications, Erbil, Iraq, 2018, pp 268-282
[26] Al-Radi, H., Al-Bukhaiti, K. and Wei, J. L., Comparison Between Static and Dynamic Laboratory Compaction Methods. Journal of Engineering and Applied Sciences, Vol. 1, Issue 1, 2018, Pp 34-48.
[27] Shankar, S. and Ravi, Y., In-Situ Strength Evaluation of Pavement Layers of Low Volume Road Using Dynamic Cone Penetrometer (DCP). Transactions of Engineering and Sciences, Vol. 2, Issue 8, 2014, pp. 42-47.
[28] Mousavi S. H., Gabr M. A., and Borden R. H., Resilient Modulus Prediction of Soft low Plasticity Piedmont Residual Soil Using Dynamic Cone Penetrometer. Journal of Rock Mechanics and Geotechnical Engineering, Vol. 10, Issue 2, 2018, pp. 323-332.
[29] Altaf Hossain M. and Palit, S. K., Evaluation of Road Pavement Using Dynamic Cone

Penetrometer. International Journal of Civil Engineering, Vol. 4, Issue 9, 2017, Pp 14-22.
[30] Ilori A. O., Assessing the Unpaved Shoulder of an Airport Runway for Pavement Construction Using the Light Weight Penetrometer LRS 10, Innovative Infrastructure solutions, Vol. 3, Issue 1, 2018, pp 77-81
[31] Rolt, J. and Pinard, M. I., Designing Low Volume Roads Using Dynamic Cone Penetrometer, Proceedings of the Institution of Civil Engineers: Transport, Vol. 169, Issue TR3, 2016, pp. 163-172.
[32] Zhang, D., Cai, L. and Zhou, S., An Airfield Soil Pavement Design Method Based on Rut Depth and Cumulative Fatigue. Journal of Advanced Transportation, Vol. 2019, 2019, pp. 1-12.
[33] Chennarapu, H., Garala, T. K., Chennareddy, R., Balunaini, U. and Reddy, G. V. N., Compaction Quality Control of Earth Fills Using Dynamic Cone Penetrometer. Journal of Construction Engineering and Management, Vol. 144, Issue 9, 2018, pp. 04018086-1–04018086-10.
[34] Zheng, J. Yao, Y. Zheng, J. and Huang, X., Measurement of Degree of Compaction of Fine-Grained Soil Subgrade Using Light Dynamic Penetrometer, Vol. 2018, 2018, Pp 1-8.
[35] Quansah, A., Ntaryamira, T. and Obeng-Atuah, D., Evaluation of Pavement Structural Life Using Dynamic Cone Penetrometer, International Journal of Pavement Engineering, 2018, pp. 1-7
[36] Beeghly J. H. Recent Experience with Lime – Fly ash Stabilization of Pavement Subgrade Soils, Base and Recycled Asphalt. International Ash Utilization Symposium, Center for Applied Energy Research, University of Kentucky, 2003, pp. 1-18.
[37] Gregory E. and Halsted P. E. Using Cement to Reclaim Asphalt Pavement. Annual Conference of the Transportation Association of Canada, Saskatoon, Saskatchewan, 2007, pp 1-20.
[38] Edeh J. E., Eberemu A. O., and Agnes O., Lateritic Soil Stabilization of Reclaimed Asphalt Pavement as Flexible Highway Pavement Materials. Advances in Materials Research, Vol. 367, 2012, pp. 3-11.
[39] Nigerian General Specification for Roads and Bridge Work, Federal Ministry Of works, Lagos, Nigeria, 1997.
[40] Edeh J. E., Eberemu A. O., and Abah A. B. Reclaimed Asphalt Pavement-lime Stabilization of Clay as Highway Pavement Materials. Journal of Sustainable Development and Environmental Protection, Vol. 2, Issue 3, 2012, pp. 62-75.
[41] Bleakley A. M., and Cosentino P. J. Improving the Properties of Reclaimed Asphalt Pavement for Roadway Base, Application through Blending and Chemical Stabilization. Annual Meeting of Transport Research Board, vol. 2335, Issue 1, 2013, pp. 20-28.
[42] Ochepo J., Stabilization of Lateritic Soil Using Reclaimed Asphalt Pavement and Sugarcane Bagasse Ash, for Pavement Construction. Journal of Engineering Research, Vol. 2, Issue 4. 2014, pp. 1-13.
[43] Mishra B., A Study on Use of Reclaimed Asphalt Pavement Materials in Flexible Pavements. International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Issue 12, 2015, pp. 12170-12177.
[44] Kamel M. A., Al-Bustami N. M., and Alsulami B. T., Evaluation of the Suitability of Recycled Asphalt Pavement (RAP) for Sub-bases. International Journal of Emerging Technology and Advanced Engineering, Vol. 6, Issue 5, 2016, pp. 212-215.
[45] Avirneni D., Peddinti P. R. T. and Saride S., Durability and Long term Performance of Geopolymer Stabilized RAP Base Courses. Construction and Building Materials, Vol. 121, 2016, pp. 198-209.
[46] B. T. Nguyen and A. Mohajerani. A new lightweight dynamic cone penetrometer for laboratory and field application. Journal and News of the Australian Geomechanics Society, Vol. 47 No.2, pp. 41-50, 2012.
[47] R. S. Kumar, A. S. Ajmi, and B. Valkati. Comparative Study of Sub grade Soil Strength Estimation Models Developed Based on CBR, DCP and FWD Test Results. International Advanced Research Journal in Science, Engineering and Technology, Vol. 2, Issue 8, 2015, pp. 92-102.
[48] Tran Q. A., Chevalier B., Benz M., Breul P. and Gourves R. Modelling of Light Dynamic Cone Penetration Test – Panda 3(R) in Granular Material by Using 3D Discrete Element Method. EPJ Web of Conferences, Powder and Grains, Vol. 40, 2017, pp. 1-4.
[49] B. S. 1377, Methods of testing soil for civil engineering purposes, British standards institute London, 1992.
[50] TRL, Transportation: Past, Present and Future Conference, Transportation Association of Canada, Montreal, Quebec, 2014, pp. 1-13.