2nd International Civil Engineering Conference (ICEC 2020)
Department of Civil Engineering
Federal University of Technology, Minna, Nigeria

Development of an Empirical Model for A-6 Soil Stabilised with Reclaimed Asphalt Pavement

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ABSTRACT
A-6 lateritic clay is a weak soil, which requires some forms of stabilization and strength enhancement. The clay soil was obtained from predetermined depths. It was first compacted and then stabilized with 0, 10, 20, 30, 40 and 50% of Reclaimed Asphalt Pavement respectfully. The compaction was correlated with the strength developed by A-6 clay soil stabilised with Reclaimed Asphalt Pavement. The compaction results of clay-RAP mix ranged from 0.553 - 1.995 g/cm^3 for MDD, with 7.10 - 9.90% for OMC. The CBR values of samples ranged between 11% and 19.3%. Finally, using OMC as independent variable, an empirical model, MDD = – 0.348x+3.094 was developed using Microsoft Excel 2017. The model was satisfactory for sub-grade application. Also, the CBR value of 17.2 – 19.3% is satisfactory for both sub-grade and sub-base use according to General specification. The Model gave an excellent strength correlation R^2 of 0.97.

Keywords: *Compaction, Clay soil, Microsoft Excel 2017, Reclaimed Asphalt Pavement, Stabilization.*

1 INTRODUCTION

In civil engineering, soils with properties that cannot be safely and economically used for the construction of civil engineering structures without adopting some stabilization measures are known as problem soils. They are expansive and collapsible soils. To the geotechnical and highway engineers, a problem soil is one that poses problem to construction. Such problems may be as a result of instability of the soil which makes it unsuitable as a construction material in foundations, buildings, highways, water retaining structures and dams. Clay is predominant in most of the subgrade soil materials of Nigeria. The clay minerals attract and absorb water, thereby making it highly susceptible to swelling and shrinkage respectively (Ola, 1987).

Soils are classified into eight groups, A-1 through A-8. The major groups A-1, A-2, and A-3 represent the coarse grained soils and the A-4, A-5, A-6, and A-7 represent fine grained soils. A-8 are identified by visual inspection. A-6 group of soil classification system, includes those materials which have high plasticity indexes in relation to liquid limit and which are subject to extremely high volume change (AASHTO, 1986).

Reclaimed asphalt pavement (RAP) is an existing asphalt mixture that has been pulverized, usually by milling, and is used like an aggregate in recycled asphalt pavement (Jeff and Miles, 2006). During pavement rehabilitation and reconstruction, large quantities of this materials are generated especially when asphalt pavement are removed. RAP is the term given to reprocessed and/or removed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for reconstruction, resurfacing, or to obtain access to buried utilities. The binder in the RAP after several years of service, becomes aged and much stiffer than desired. Experience has indicated that the recycling of asphalt pavements is a beneficial approach from technical, environmental, and economical perspectives (Chen, 2007). This has made the recycling of pavement materials to become a very viable alternative to be considered in road maintenance and rehabilitation with the conservation of resources, preservation of the environment, and retention of existing highway geometrics; are some of the other benefits obtained by reusing pavement materials.

In Nigeria however, RAP recovered during highway reconstructions and rehabilitations are kept along road alignments and the statistics of the amount of RAP recovered is not documented. The use of waste materials, particularly RAP in the construction of pavements has benefits in not only reducing the amount of waste materials requiring disposal but can also provide construction materials with significant savings over new materials. Hence, the use of RAP can actually provide value to what was once a costly disposal problem. Initially, this recycling was limited to the re-use of materials removed from previous pavement structures such as: recyclable asphalt pavement, recyclable portland cement concrete and various base course materials but recently various other materials, not originating or associated with pavements, have come into use, either as additives or pozzolan to improve the particle size distribution, physical, chemical, engineering and mechanical properties of RAP (Hanks and Magni, 1989; FHWA, 1999).

However, the effect of RAP on A-6 Soil, using a linear regression analysis model to determine the strength characteristics of the lateritic soil RAP mix; by carrying out a CBR test at different percentages is intended in this work. This will be very essential for Geotechnical engineers on proper application of RAP in the stabilization of A-6 soil as material in pavement construction. Hence, the linear regression analysis shall reveal the strength characteristics of the soil RAP mix; at different percentages of the CBR test to be carried out.

2. METHODOLOGY

2.1 Materials

Soil: The soil used in this study was collected using the disturbed sampling technique at depths of between 0.5 m and 2.0 metres from borrowed pits around Talba farm area, a suburb of Minna, Niger State, Nigeria. It is a lateritic soil later classified using index properties tests conducted.

Reclaimed Asphalt Pavement: The reclaimed asphalt pavement used in this work was sourced from the ongoing Minna to Suleja road Duallization/rehabilitation Nigeria. The Reclaimed Asphalt Pavement (RAP) was sieved through sieve No 200 of the BS sieve to get very fine grain. It was thereafter collected in a container as shown in plate I.

Plate I: Reclaimed Asphalt Pavement

Microsoft Excel 2017: Excel is a commercial spreadsheet application produced and distributed by Microsoft for Microsoft Windows and Mac OS. It features the ability to perform basic calculations, create pivot tables and create macros, also use graphing tools as well. Excel permits users to arrange data so as to view various factors from different perspectives. Visual Basic is used for applications in Excel, allowing users to create a variety of complex numerical methods. Programmers are given an option to code directly using the Visual Basic Editor, including Windows for writing code, debugging and code module organization.

Excel has the same basic features as all spreadsheet applications, which use a collection of cells arranged into rows and columns to organize and manipulate data. They can also display data as charts, histograms and line graphs.

2.2 Test Methods

Index Properties: Natural moisture content, specific gravities, particle size analysis and Atterberg limits tests were conducted in accordance with tests procedures specified in BS 1377: 1990.

Compaction Characteristics: Compaction of stabilized A-6 soil specimen and Reclaimed Asphalt Pavement was conducted in accordance with the guidelines specified in BS 1377-2, (1992) to compute the required parameters. The British Standard Heavy Weight (BSHW) compactive effort was used. The BSHW compaction is the energy resulting from 4.5 kg rammer falling through a height of 30.5 cm onto five layers, each receiving 25 blows.

California Bearing Ratio (CBR): The unsoaked CBR of stabilized A-6 soil specimen and Reclaimed Asphalt Pavement was conducted in accordance with the guidelines specified in BS 1377 (1992). Hence, 6 kg of pulverized mixed samples divided to five parts were poured into CBR mould and rammed with 4.5 kg rammer into five layers, each receiving 62 blows. The attached upper and lower dial gauges measures the upper and lower penetrations of the plunger.

Plate II: California Bearing Ratio test of samples

Regression Analysis Model: The linear equation for this model is MDD = - 0.348x+3.094 where the OMC is the independent variable and the MDD is the dependent variable. An increment in MDD will lead to a decrease in OMC, likewise if MDD reduces OMC will increase.

Regression can be done manually directly from Microsoft Excel and also by encoding. Encoding helps the visual Based Analysis to run in a particular way you want, to achieve a purpose. Macros also known as Visual Based Analysis (VBA) was used to run a code generated to accommodate the accepted and specified values, and a button was created such that when clicked; the regression is generated instantly.

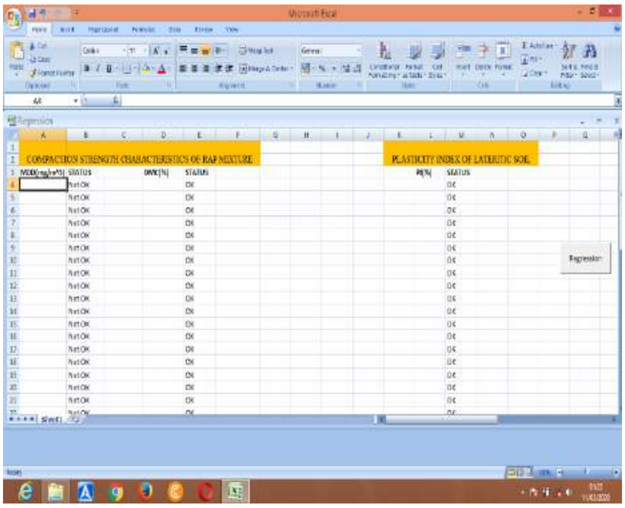
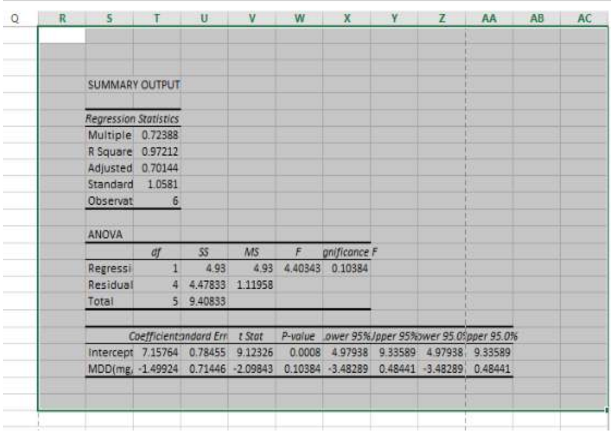


Plate III: Regression Model 1for test sample



SUMMARY OUTPUT

Regression Statistics	
Multiple	0.72388
R Square	0.97212
Adjusted	0.70144
Standard	1.0581
Observat	6

ANOVA

	df	SS	MS	F	gnificance F
Regressi	1	4.93	4.93	4.40343	0.10384
Residual	4	4.47833	1.11958		
Total	5	9.40833			

	Coefficient	andard Err	t Stat	P-value	ower 95%	Jpper 95%	ower 95.0%	pper 95.0%
Intercept	7.15764	0.78455	9.12326	0.0008	4.97938	9.33589	4.97938	9.33589
MDD(mg,	-1.49924	0.71446	-2.09843	0.10384	-3.48289	0.48441	-3.48289	0.48441

Plate IV: Regression Model 2 for test sample

3. DISCUSSION OF RESULTS

3.1 Results

Index properties of the natural soil

The index properties of the natural clay soil is shown in Table 1. The fraction passing No 200 sieve is 42.57% with liquid limit of 35.5%, plastic limit of 28.9% and plasticity index of 6.5%. The soil is classified as A – 6 according to AASHTO soil classification systems respectively (AASHTO, 1986).

Table 1: Properties of natural clay soil

Properties (Average)	Sample A
Natural moisture content of soil (%)	12.06
Atterberg Limits	
Liquid limit (%)	35.5
Plastic limit (%)	28.95
Plasticity index	6.5
% Passing BS No. 200 sieve	42.57
Classification	
USCS	CL
AASHTO	A-6

Table 2: Compaction and CBR results of test sample

RAP(%)	Compaction Characteristics		
	MDD (g/cm^3)	**OMC** (%)	**CBR** (%)
0%	0.553	9.90	11.1
10%	0.645	8.90	13.5
20%	0.890	8.50	15.5
30%	1.120	8.10	17.2
40%	1.510	7.70	18.8
50%	1.995	7.10	19.3

Effect of RAP on Compaction Characteristics of test sample

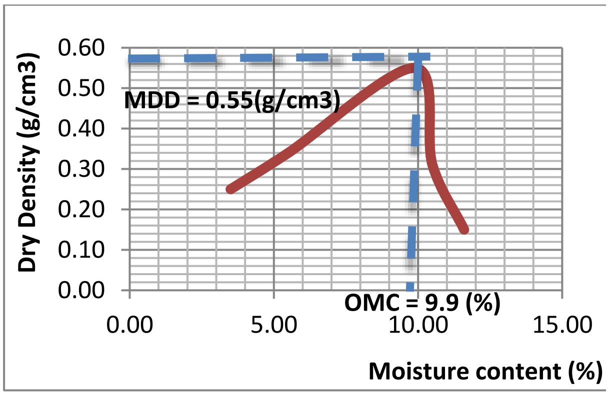


Figure 1: Compaction characteristics of stabilized clay 0% RAP

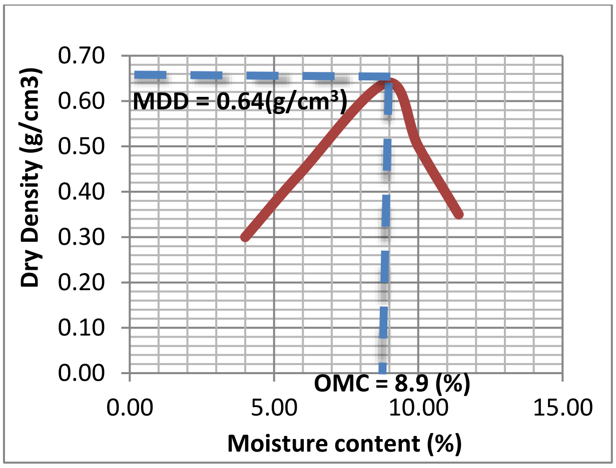


Figure 2: Compaction characteristics of stabilized clay 10% RAP

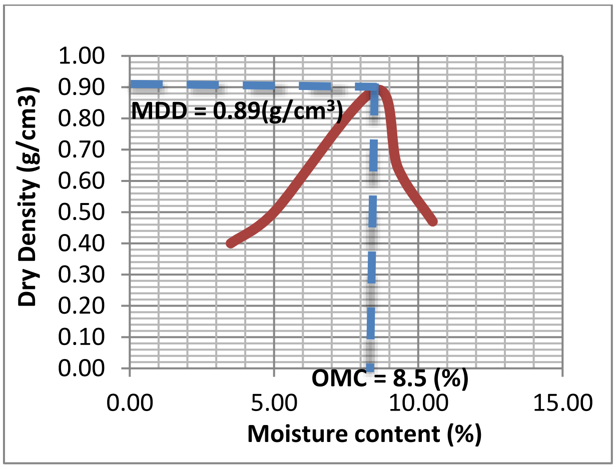


Figure 3: Compaction characteristics of stabilized clay with 20% RAP

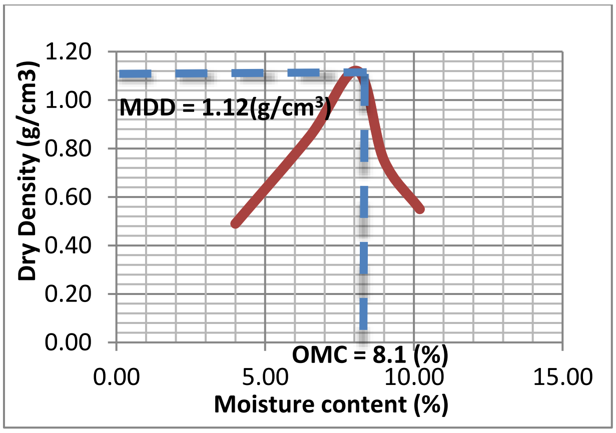


Figure 4: Compaction characteristics of stabilized soil with 30% RAP

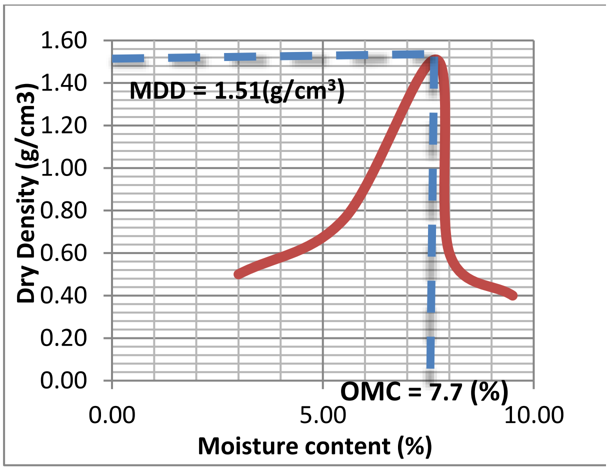


Figure 5: Compaction characteristics of stabilized soil with 40% RAP

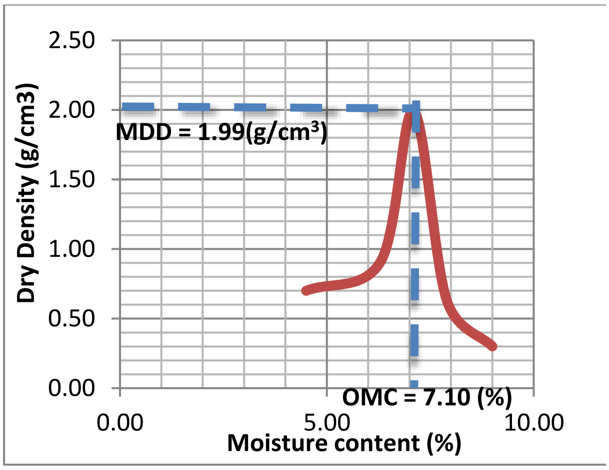


Figure 6: Compaction characteristics of stabilized soil with 50% RAP

Effect of rap on California bearing ratio of lateritic soil

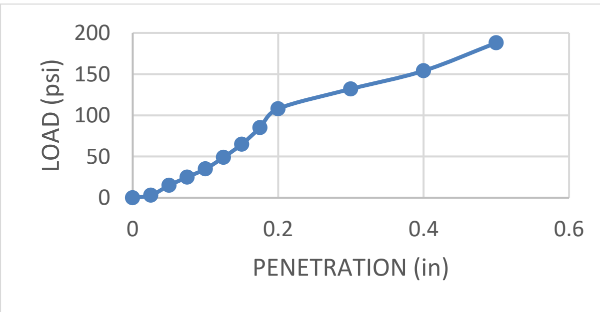


Figure 7: CBR effect on lateric soil with 0% RAP

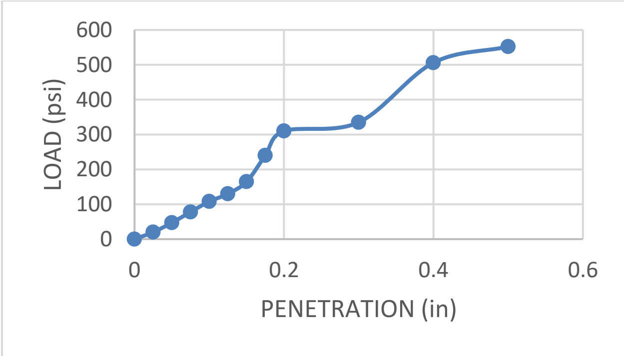


Figure 8: CBR effect on lateric soil with 10% RAP

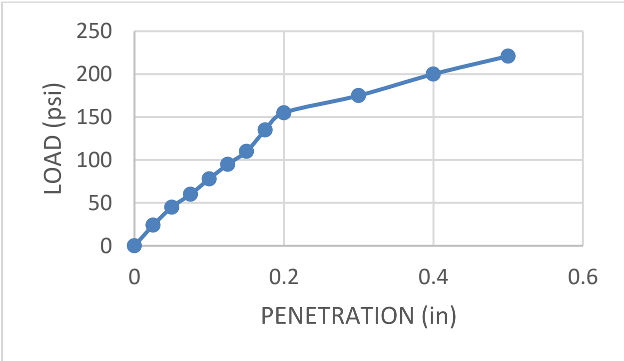


Figure 9: CBR effect on lateric soil with 20% RAP

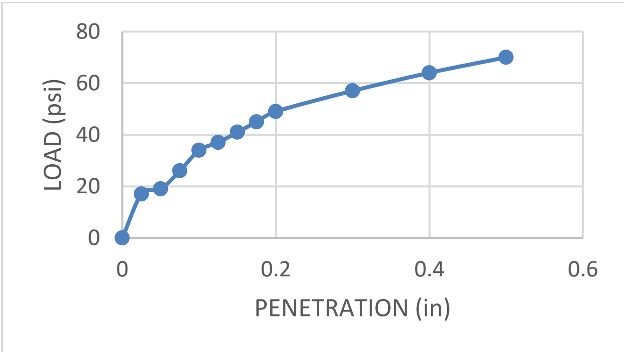


Figure 10: CBR effect on lateric soil with 30% RAP

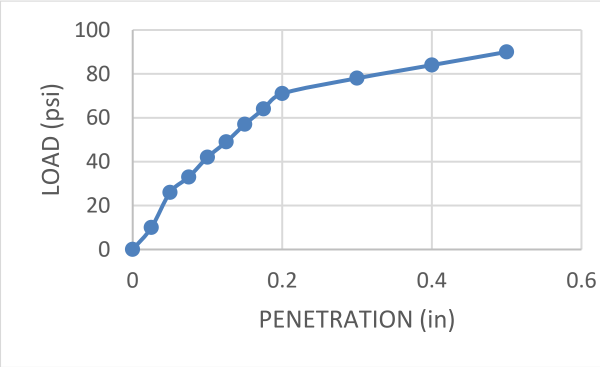


Figure 11: CBR effect on lateric soil with 40% RAP

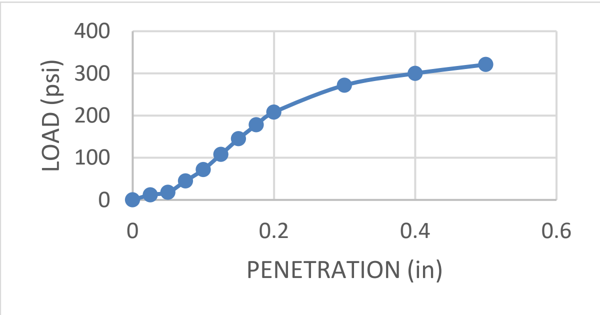


Figure 12: CBR effect on lateric soil with 50% RAP

From the index properties test results, the percentage passing sieve 200 is 42.57% while the liquid limit is 35.5%. This has fulfilled the requirement according to AASHTO classification system of having a minimum of 36% soil particles passing through sieve 200 and liquid limit having 40% maximum. Hence, the lateritic soil was classified as A-6 which indicates that it is a Silt-Clay materials. However, samples with low moisture content, are suitable for road construction and this is expected to greatly increase the shear strength of soil. The liquid limit of the lateritic soil is 35.5% which indicate the probable absence of expandable clay materials; making them suitable for sub-grade which are not greater than 40%. Federal ministry of works and housing (Nigeria) recommended liquid limit of 40% maximum for sub-grade, 35% maximum for sub-base and 30% maximum for base course. Plasticity index of 20% maximum for sub-grade, 16% maximum for sub-base and 13% maximum for base course was also recommended by FMWH. Hence, plasticity index which is 6.6% for our lateritic soil is suitable for sub-grade (FMWH 1997).

However, the result for proctor compaction test are presented in Table 2; the results indicate that at 0% of RAP, MDD is 0.553g/cm^3 and OMC is 9.90%; at 10% of RAP, MDD is 0.645g/cm^3 and OMC is 8.9%; at 20% of RAP, MDD IS 0.890g/cm^3 and OMC is 8.50%; at 30% of RAP, MDD is 1.120g/cm^3 and OMC is 8.10%; at 40% of RAP, MDD is 1.510g/cm^3 and OMC is 7.70%; at 50% of RAP, MDD is 1.995g/cm^3 and OMC is 7.10%. The Nigerian specification for Roads and Bridges Materials, shows that for a material to be suitable for construction, it should have MDD > 0.047mg/m^3 and OMC < 18%. Hence, for all percentages partially replaced with RAP, the results gotten are suitable for filling and embankment materials base on the results.

Accordingly, the CBR results are presented in Table 2; the results shows that at 0% of RAP, CBR is 11.1%; at 1% of RAP, CBR is 13.5%; at 7% of RAP, CBR is 15.5%; at 14% of RAP, CBR is 17.2%; at 28% of RAP, CBR is 18.8%; at 60% of RAP, CBR is 19.3%. Likewise, in accordance to the Nigerian General Specification for Roads and Bridges in Nigeria (1997) which recommends a maximum CBR value of 10-30% for sub-grade, the tested samples both at control and different percentage stages are excellent for sub-grade.

The Empirical model MDD = -0.348x+3.094 has the capacity to accommodate 50 samples with instant results to show if the MDD and OMC of each sample is OK for sub-grade materials. A quick Regression was done and the R^2 for satisfactory purpose also shows to be 0.97, multiple R is 0.72 and Adjusted R is 0.70. In accordance to the Nigerian Specification for Roads and Bridges Materials which recommends MDD > 0.047mg/m3 and OMC < 18% for a material to be suitable for construction, the model shows that lateritic soil at the various percentages are satisfactory for sub-grade use.

4. CONCLUSION

Thus, it becomes imperative to add to the existing knowledge by using linear regression analysis to predict the strength characteristics of the lateritic soil-RAP mix, as to when constraints sets in from the level of expertise and malfunction of equipment while determining the CBR values. It was observed that as the MDD increases from 0.553g/cm^3 at 0% RAP content to 1.90g/cm^3 at 50% RAP content, OMC decreases from 9.90% at 0% RAP content to 7.10% at 50% RAP content during compaction. The CBR ranges from 11.1 g/cm^3 at 0% RAP content to 19.3% at 50% RAP content. Finally, the Empirical model MDD=-0.348x+3.094 can be used to ascertain the strength characteristics of the lateritic soil-RAP mix, when related to the CBR results which is satisfactory for sub-grade purpose and sub-base application.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions of colleagues and technologists in Federal University of Technology, Minna.

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