Assessment of Subgrade Soils of parts of the Lower Benue Trough using California Bearing Ratio (CBR).

N.E. Ekeocha* **and E.G. Akpokodje**

Department of Geology, University of Port Harcourt, PMB 5323, Port Harcourt, Rivers State, Nigeria.

E-mail: nnamdi.ekeocha@uniport.edu.ng*
eknainb@yahoo.co.uk

ABSTRACT

Road failure in the region under study has become worrisome. In view of the severity and the fact that the failed sections overlie shale layers within the area, assessment of the subgrade soils using California Bearing Ratio (CBR) was embarked upon to verify the contribution of the underlying shale to the failure of the soils. The consistency and particle distribution of the samples were also determined, with resulting values of 22 – 98%, 4 – 93%, 1 – 76%, respectively, for liquid limit, plastic limit and plasticity index. The samples classified as slightly - extremely plastic. The clay fraction recorded between 2 and 8% while the average CBR value of the unsoaked sample ranged between 5.5 and 10.9% at optimum moisture content (OMC) of between 11.2 and 14.4%. The CBR of the samples conforms to the Federal Government standard design specification. The liquid limits and plasticity index values on the other hand far exceed those specified by the FGN, thereby supporting the observed failure pattern. This therefore underscores the need for proper evaluation of the materials prior to use for construction and adequate stabilization of such materials as would show poor quality in comparison with specifications.

(Keywords: road failure, construction, stabilization, California Bearing Ration, CBR, soil classification, optimum moisture content, OMC)

INTRODUCTION

It has been observed that significant sections of the Port Harcourt–Enugu expressway have broken down (Plate 1) greatly to the point that these sections have to be avoided by the use of detours, thereby increasing the difficulties encountered by users of the road.

Plate 1: Typical Failure Pattern.

This kind of failure, which agrees with Akpokodje *et.al*. (1985) and Uduji *et. al*, (1994), is observed within sections of the road underlain by shales, which naturally do not form good road construction materials. O' Flaherty (1974) described shale as essentially a clayey material, which is very likely to break down in the presence of moisture and frost. Since shale is highly clayey in nature, it is subjected to swelling during the rainy season and shrinking during the dry season. Abeyesekera *et. al.* (1978) described shale as a notoriously unpredictable material, in which a number of failures have been reported involving settlement and shear failure of compacted shale embankments. Geologically, the region through which the expressway runs has several shale formations (e.g., Imo, Awgu, Nkporo, Enugu and Asu River Group) of varying ages and degrees of weathering, some of which are exposed along the expressway.

Shales, by definition, are fine-grained rocks that contain between 50% and 100% clay sized particles with clay mineral constituting at least 25% of the total rock volume. Shales when highly indurated may be used as construction materials because of their intermediate hardness. They are also known to possess a degree of intactness, continuity and strength.

DESCRIPTION AND GEOLOGY OF STUDY AREA

The study was carried out within parts of the Lower Benue Trough of the South Eastern part of Nigeria. The study area is located within the geographical coordinates of between 5°40' and 6° 25'N and between 7° 15' and 8° 23'E (Figure 1).

The geology of the area has been severally described (Reyment, 1965; Agagu *et.al.*, 1985; etc.), and is believed to be associated with the tectonic activities that were recorded during the Cenomanian. These tectonic activities produced an uplift that had a NE-SW trend. This gave way to the tectonic activities that took place in Santonian times (i.e. the second tectonic activity of the Lower Benue Trough), which resulted in the folding and uplifting of the Abakaliki Sector of the Trough and the subsidence of Anambra platform. The latter event led to the formation of the Anambra Basin, which constituted a major depocenter of clastic sediments and deltaic sequences.

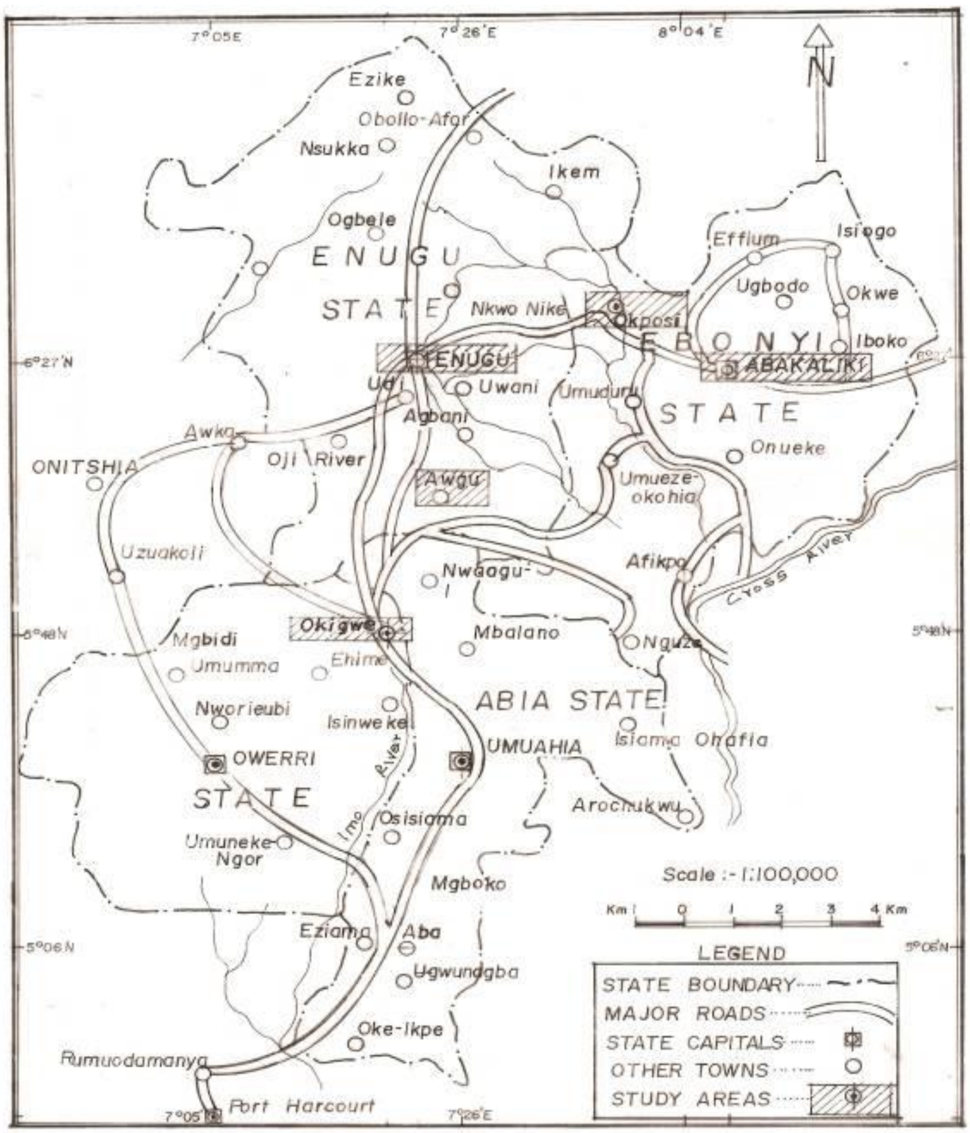

Figure 1: Map of the Study Area.

The age of the sediments in the Basin ranges from Pre-Cretaceous to Recent. Awgu shales which were deposited during the Coniacian times are the oldest formation in the Anambra basin section of the study area. It overlies the Eze-Aku Group and its lateral equivalent, the Agbani Sandstone.

The erosion of the Abakaliki uplifted and folded belts resulted in the development of a Proto-Niger Delta sequence consisting of Enugu shale, Mamu, Ajali and Nsukka Formations. The third and last depositional cycle of the Lower Benue Trough started with a major transgression that deposited the marine Imo shales in the Anambra basin, during the Palaeocene Period. This was followed by a regression that started during the Eocene and continued to the present day with the deposition of the sediments of the Tertiary Niger Delta. The sediments deposited during this period included the Bende – Ameki, Nanka, Ogwashi – Asaba and the Coastal Plain Sands (Benin) Formations in that sequence.

METHOD OF STUDY

Liquid Limit

The liquid limit test was carried out using the ASTM method and this involved the determination of the water content at which 25 numbers of blows brought about the closure of the grove opening made on samples placed on the Casagrande apparatus.

Plastic Limit

This analysis was done by adopting the ASTM method "for determination of properties of soils and rocks". It involved the determination of the water content of the sample when threads of the sample 1/8" in diameter started to crumble. This was done a number of times for a particular sample and the mean of the results was determined for a scientific representation. The crumbling is manifested in the development of hair-like cracks on the rolled samples.

Penetration Characteristics using California Bearing Ratio (CBR)

The basic CBR test, which was carried out on compacted samples in the laboratory, both in soaked as well as unsoaked states, consists of causing a plunger of standard area to penetrate a sample. The load required to cause the penetration is plotted against measured penetration, the readings noted at regular intervals of time. The information is plotted on a standard graph where the plot of the test data will establish the CBR result.

The analysis was carried out according to BS 1377: Soils for civil engineering purposes: Part 4, Compaction related tests.

TEST RESULTS AND DISCUSSION

Consistency is used to show the degree of firmness of cohesive soils and for cohesive soils, it is qualitatively expressed as very soft, stiff, very stiff and hard. Atterberg limits constitute one way of expressing the consistency of a soil. On the other hand, the consistency index, which is given by the ratio of the difference between the liquid limit and the moisture content to the difference between the liquid limit and the plastic limit (i.e. plasticity index) of the samples from the studied various shale deposits range from 0.1 to 52 for samples 1 - 3, 0.0 to 10.3 for samples 4 – 6 and 1.22 to 15 for samples 7 - 9 respectively. The consistency of fine soils as shown by Bell (2007) is adopted in comparing the shale samples in terms of consistency (Table 2).

Plasticity

The results of the various tests are presented in Table 1. The liquid limits range of 23 to 109% were obtained while the plastic limit varied from 18 to 93%. The attendant plasticity index was between 1 and 76%.

The above result shows that the samples classify on Bell's (2007) plasticity scheme according to liquid limit (Table 2) as follows:

Samples 1 – 3 classify as low to extra high.
Samples 4 – 6 classify as intermediate to extra high.
Samples 7 – 9 classify as low to intermediate plasticity.

The results above suggest that the samples will exhibit poor engineering qualities because they show great tendencies to lose moisture when they get exposed to dryness.

Table 1: Results of Laboratory Analysis.

Location	Average Soaked CBR (%)	Average Unsoaked CBR (%)	% Fines	OMC (%)	MDD (kg/m^3)	Liquid Limit	Plastic Limit	Plasticity Index
1	14.5	10.7	<5	12.3	1794	23	22	1
2	5.5	10.7	<5	12.5	1748	75	18	57
3	5.5	10.7	<5	11.2	1742	105	93	12
4	7.1	9.5	<5	13.4	1705	50	49	1
5	6.8	9.4	<5	14.4	1725	77	28	45
6	7.1	9.4	5	12.6	1692	109	33	76
7	7.1	9.5	<5	14.2	1785	32	30	2
8	10.8	5.5	5	12.6	1708	47	31	16
9	15.2	10.9	10	12.0	1774	59	27	32

Table 2: Plasticity According to Liquid Limit (after Bell, 2007).

Description	Plasticity	Range of Liquid Limit
Lean or Silty	Low Plasticity	<35
Intermediate	Intermediate plasticity	35 – 50
Fat	High Plasticity	50 – 70
Very fat	Very High plasticity	70 – 90
Extra fat	Extra High Plasticity	>90

The plasticity of clay soil is influenced by the amount of its clay fraction and the type of clay minerals present, since the amount of attracted water held in a soil is influenced by clay minerals. As a consequence, the index properties of clay deposits are influenced by the principal minerals in the clay. This is consistent with Sabtan's (2005) assertion that the Hanadir shale is the source of expansive soils in the area and that the shale composition and its engineering properties change abruptly in both horizontal and vertical directions due to both the rock nature (grain size, plasticity, mineralogy, and cementation) and degree of weathering.

There is a general correlation between the clay mineral composition of a deposit and its activity.

Figure 2 shows the plasticity plot of the various shale samples on the Casagrande chart. The ranges of plasticity index of the shale samples indicate that the samples range from non-plastic to extremely plastic.

The plot shows that the samples classify as follows:

Shale samples 1 - 3: clays with intermediate to high compressibility characteristics

Shale samples 4 – 6: clays and silt of high compressibility (i.e. CH/MH & OH)

Shale samples 7 - 9: mostly as clays of intermediate to low compressibility (MI & OL) with few showing high compressibility tendencies (i.e. MH).

There is an observed trend of relationship to the effect that samples with higher plastic limits recorded lower moisture content and higher consistency index. It is also observed that the higher the liquid limit, the higher the compression index computed from liquid limit.

Penetration Characteristics using CBR

The California Bearing Ratio (CBR) was developed by the California State Highways Department, to evaluate the strength of road subgrades. According to Krynine and Judd (1957) and Garg (2009), it is widely used in the design

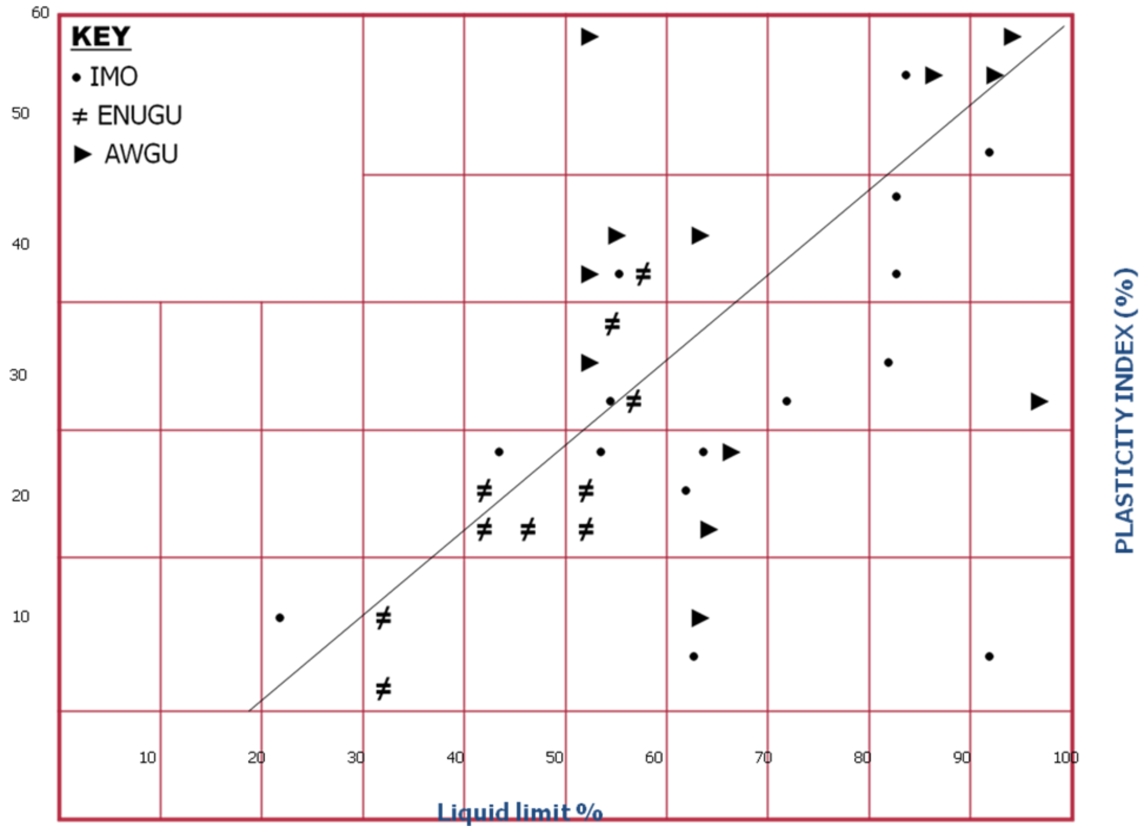

Figure 2: Plasticity Plot of the Various Samples.

of flexible airport and highway pavements and sometimes in the specifications for the use of earth materials for various construction purposes. It is considered to give reliable results, provided the tests are conducted according to specified conditions. The higher the CBR value, the better the material.

CBR test was conducted on samples collected from nine (9) locations between Umuahia and Awgu, where road failures are very severe at the time of the study, and it is thought that these failures may have been caused by the underlying shale subgrades. The results are presented in Table 1 while the CBR and compaction plots are shown in Figures 3 and 4.

According to Table 1 above, the analysed samples revealed that the subgrades recorded strength values within grade ranges of normal to good (5-11%). Though the values of the CBR are in consonance with the specifications of the Federal Government standard pavement design specification, the liquid limit and plasticity index values of the samples far exceed those specified by the Federal Government, thereby justifying the extensive failures that mostly occur during the rainy season in sections where the running surface is damaged. Also the studied samples were partly weathered shales which were not completely broken down into individual grains and as a result yielded low quantity of fines.

CONCLUSION

The observation that the materials classify within the normal to good range is a source of concern as the failure recorded in the area is in sharp contrast with this observed material grade. It is therefore significant that adequate evaluation be carried out prior to use of such materials for construction and proper stabilization techniques adopted as may be required to achieve compliance with specifications.

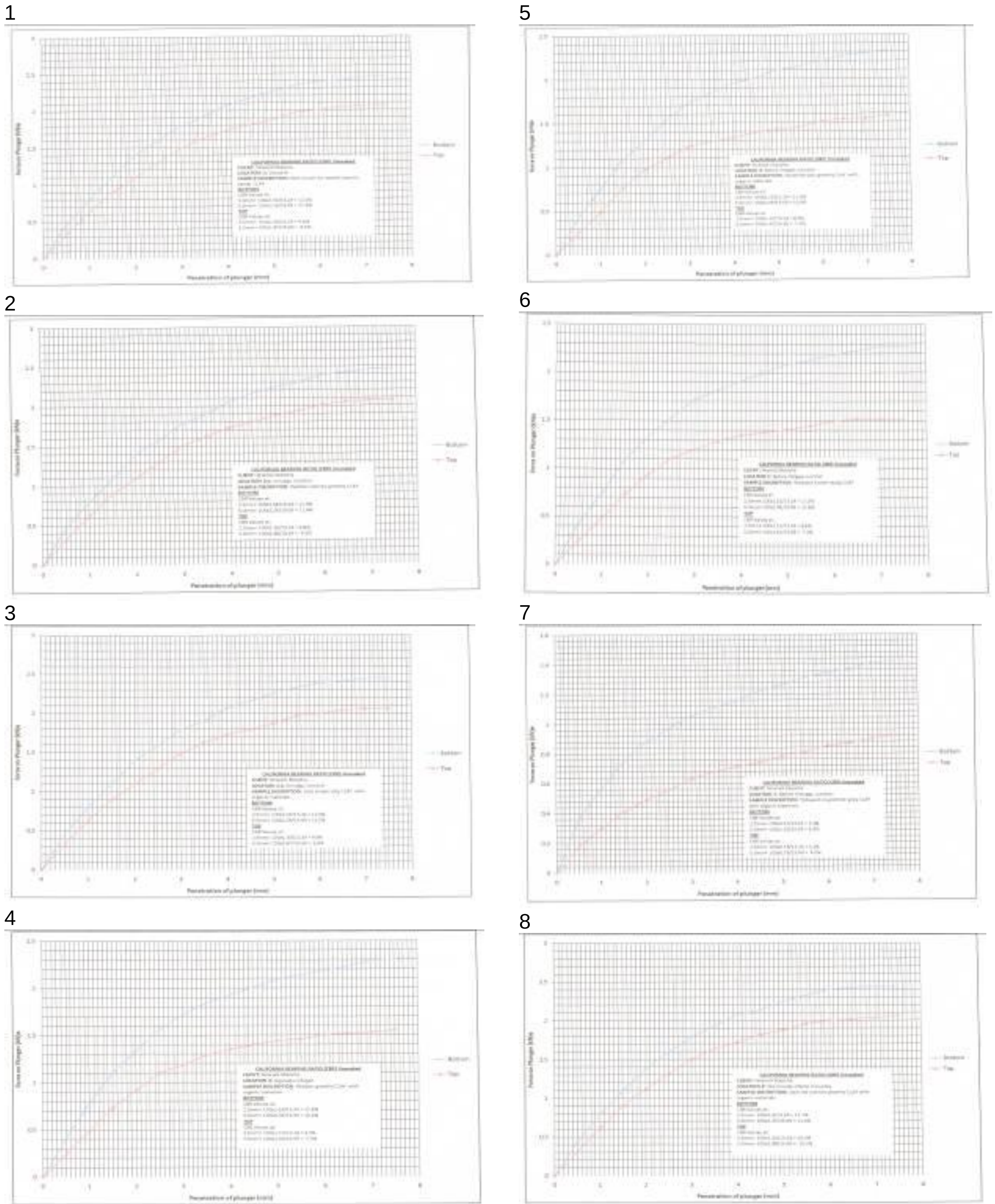

Figure 3: CBR Plots for the Samples.

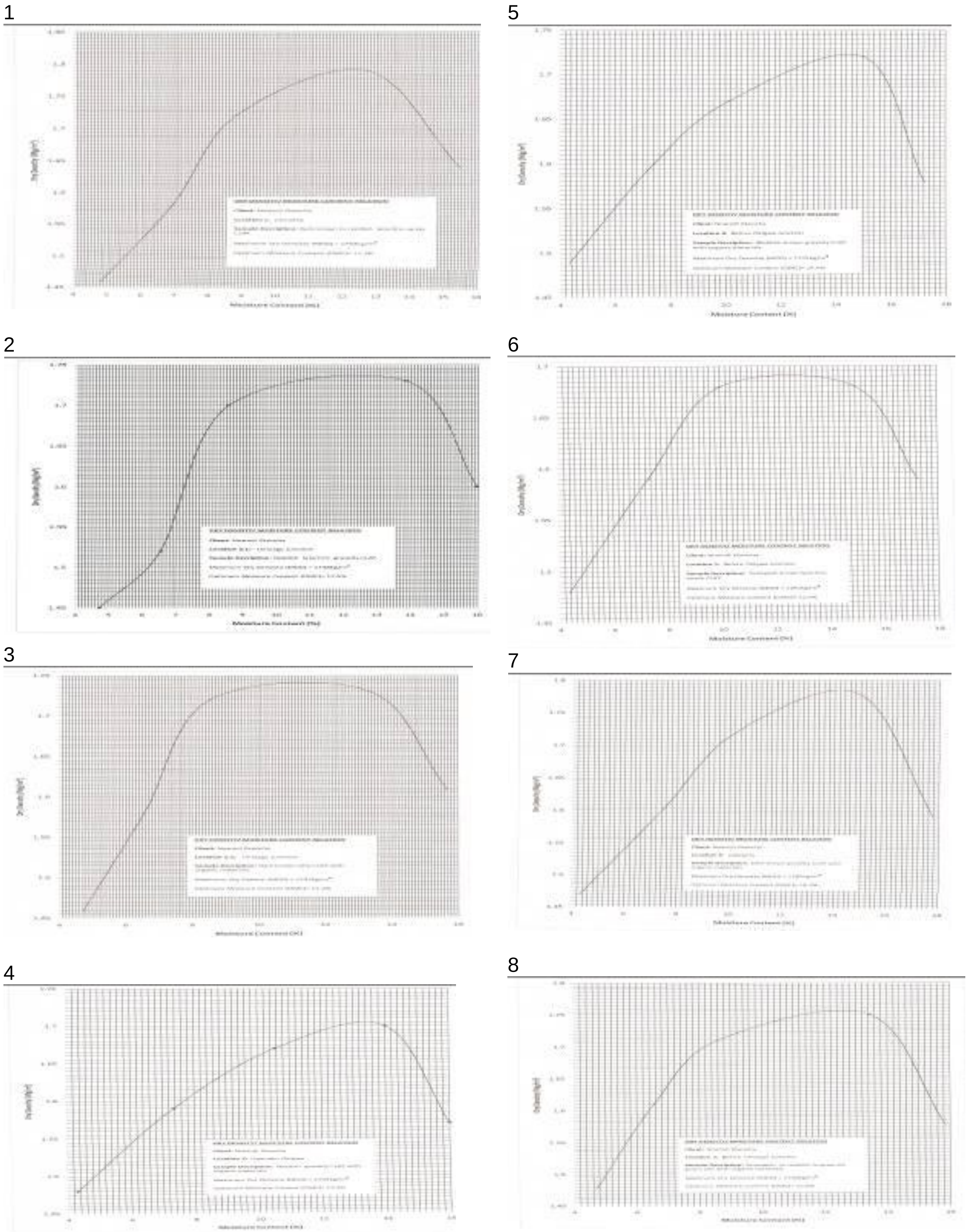

Figure 4: Compaction Curves showing the OMC & MDD.

REFERENCES

1. Abeyeskera, R.A, C.W. Lovell, and L.E. Wood. 1978. "Stress Deformation and Strength Characteristics of a Compacted Shale Clay fills". Institution of Civil Engineers: London, UK.1-14.

2. Agagu, O.K., E.A. Fayose, and S.W. Petters. 1985. "Stratigraphy and Sedimentation in the Senonian Anambra Basin of Eastern Nigerian". *Nig. Journ. Min. & Geol*. 22.

3. Akpokodje, E.G. 1985. "The Stabilization of Some Arid Zone Soils with Cement and Lime". *Quarterly Journal of Engr. Geology, London*. 18.

4. Bell, F.G. 2007. *Engineering Geology, 2nd Edition*. Elsevier: London, UK. 207-248.

5. Garg, S.K. 2009. *Soil Mechanics and Foundation Engineering, 7th ed.* Khanna Publishers: New Delhi. India. 673- 683.

6. Krynine, D.P. and William, J.R. 1957. *Principles of Engineering Geology and Geotechnics*. McGraw – Hill: New York, NY. 159, 537.

7. O' Flaherty, C.A. 1974. *Highway Engineering, Vol. 2.* Edward Arnold: London, UK. 95.

8. Okogbue, C.O. 1985. "Evaluation of Strength Properties of Mineral Soil". *Nig. Journ. Min. & Geol*. 22(1 & 2): 89 – 97.

9. Okogbue, C.O. and G.E. Ene. 2008. "Geochemical and Geotechnical Characteristics and the Potential for use in Drilling Mud of Some Clay Bodies in Southeastern Nigeria". *Journ. Min. & Geol.* 44(2):121 – 130.

10. Sabtan, A.A.. 2005. "Geotechnical Properties of Expansive Clay Shale in Tabuk, Saudi Arabia". *Journal of Asian Earth Sciences*. 25:747 – 757.

11. Uduji, E.R., C.O. Okagbue, and T.U.S. Onyeobi. 1994. "Geotechnical Properties of Soils Derived from the U and Mamu Formations in the Enugu – Okigwe Area of South Eastern Nigeria and their Relations to Engineering Problems". *Nig. Journ. Min. & Geol.* 30(1):117 – 123.

SUGGESTED CITATION

Ekeocha, N.E. and E.G. Akpokodje. 2012. "Assessment of Subgrade Soils of parts of the Lower Benue Trough using California Bearing Ratio (CBR)". *Pacific Journal of Science and Technology*. 13(1):572-579.

Pacific Journal of Science and Technology