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COMPACTION CHARACTERISTICS OF IGUMALE SHALE

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ABSTRACT

This paper reports the outcome of an investigation into the effect of different compactive energies on the compaction characteristics of Igumale shale, to ascertain its suitability as fill material in highway construction. Tests were conducted on specimen of Igumale shale, which included classification, compaction using three compactive energies in the laboratory (British standard light, West African standard and British standard heavy), and unsoaked and four-day soaked California bearing ratio (CBR) test. Results showed that Igumale shale was an A-7-6 soil. Maximum dry density (MDD) increased, while optimum moisture content (OMC) decreased with increase in compactive energy. The MDD of samples 1 and 2 increased from 1.53 Mg/m^3 and 1.59 Mg/m^3 to 1.90 Mg/m^3 and 1.89 Mg/m^3 while the OMC decreased from 19.1 % and 16.8 % to 14.3 % and 13.0 % respectively. The unsoaked CBR of samples 1 and 2 increased from 16.1 % and 10.1 % to 40 % and 37.5 % respectively. A similar trend was observed for the four-day soaked CBR values. The study showed that Igumale shale is not suitable for use as base, subbase and filling materials in road construction. However, chemical stabilization with higher compactive energy can be applied for better improvement.

KEY WORDS: Igumale shale, Compaction Characteristics, Compactive energies,

INTRODUCTION

The engineering performance of soil can be improved by compaction. Compaction is the process in which rapid reduction in volume takes place due to suitable application of loads as caused by ramming, tamping, rolling and vibration. Compaction rearranges the soil particles into a closer state of packing, and generally results in higher shear strength, lower compressibility, increased stability and bearing capacity; and reduced susceptible to water content changes (Ramamurthy and Sitharam, 2008; Murthy, 2008; Matawal, 2009).

Although many early fills were built without any special effort to compact them, some engineers recognized the importance of compacting soil to produce a strong, settlement-free, water-resistant mass as early as the nineteenth century. Animals were used as compaction “equipment” on some projects, for example, a team of 115 goats was used to compact an earth dam near Santa Fe, New Trampled cattles and heavy logs were also used to compact earth. Heavy rollers, pulled by horses were also used for compaction but by 1920, the horses had been replaced with tractors. The cost of such crude work was often more than the value of compaction. On the other hand, earth that was merely dumped in place without compaction sometimes failed under load and usually continued to settle for decades, hence necessitated research into the theory of compaction.

In 1933 Proctor first conducted tests on compaction for application to construction of earth fill dams in California. Results published by Proctor (1933) showed that with a given amount of compaction, there exists for each soil a moisture content, termed the optimum moisture content (OMC) at which a maximum dry density (MDD) is obtained (Murthy, 2008; Ramamurthy and Sitharam, 2009).

Further developments in the twentieth century enhanced the capabilities of compaction equipment, today there are available varieties of corresponding compaction energies (Coduto, 1999). According to Daniel and Wu (1993), the likely compaction energies encountered in the field can be simulated in the laboratory with standard Proctor and British standard heavy in accordance with BS 1377 (1990) as well as West African standard compaction in accordance with the Nigerian General Specification (1997).

Compaction carried out on fills, embankments and earth dams has been reported to have improved almost all the engineering properties such as increase in density and shear strength, decrease in permeability and compressibility (Bowles, 1978; Matawal, 1991; Brink *et al.,* 1992; Azizi, 2000; Mustapha, 2007). Even for stabilized soils, compaction is carried out on all the admixture ratios and the compaction parameters determined for onward design of the stabilized road on site. In order to achieve all these improvements on site to the highest proportion, 95 % and above of laboratory maximum dry density are usually specified on site (Gurcharan and Jagdish, 1991).

Osinubi *et al.,* (2008) applied three compactive efforts: British standard light, West African standard and British standard heavy compaction on lateritic soil treated with blast furnace slag and reported improvement in unconfined compressive strength, reduction in volumetric strain and hydraulic conductivity from British standard light, to British standard heavy compaction.

A lot of studies has been conducted on the properties of Igumale shale but very little is available on the behaviour of the shale under various compaction energies. Thus the objective of this study is to examine the characteristics of Igumale shale using three compactive energies so as to predict its usage as a material for road construction.

Igumale town is the headquarters of Ado Local Government Area of Benue State in Nigeria. It is about 150 km from Makurdi, the state capital. It lies between latitude $6^{0}30^{1}$ and 7^{0} North, and longitude $6^{0}30^{1}$ and 8^{0} East. The mean temperature of the region is between 26.7 – 28.9 ^{o}C. Daily maximum temperature is recorded in the months of March and April, while the minimum temperature occurs in the months of December and January. The mean minimum temperature is between 18.3 – 21.1 ^{o}C

GEOLOGY OF THE STUDY AREA

Igumale lies on Turonian sediments. Turonian was a period of wide marine transgression in Nigeria, the sea covered large parts of the Eastern and Northern Nigeria. The sediments of this stage are mainly shale, limestone and less common sandstone; marls occur locally, shale and limestone occur in alternating series.

Kogbe (1975) stated that in the Precambrian times, Nigeria consisted of uplifted landmass made up of basement sediments. The earliest marine transgression occurred during the middle-Albian and was mainly confined to southeastern Nigeria and Benue valley. During this tectonic phase, Abakaliki-Benue trough was formed (Reyment and Tait, 1983).

Reyment and Bengston (1985) described the sedimentation in the Abakiliki-Benue trough to occur in three cycles: the Asu river cycle (Mid – Albian to Cenomanian), Ezeaku cycle (Late Cenomanian to Mid – Turonian), Awgu cycle (Late Turonian to early Santonian).

Reyment and Bengston (1985) pointed out that the middle Turonian limestones and shales of Igumale Division of the lower Benue region belong to the regression phase of Ezeaku cycle.

MATERIALS AND METHODS

The samples used in this study were obtained from Igumale by digging to a depth of about 1.5 m close to cracked buildings. Previous study on the soils reported by Agbede and Smart (2004) showed that the soil contained smectite and mixed-layer illite/smectite as the dominant clay minerals. Disturbed soil samples were placed in sacks and transported to the soil mechanics laboratory of the University of Agriculture, Makurdi, where they were air dried.

LABORATORY TESTS

The liquid, plastic and shrinkage limits were determined with about 200 gm each of soil samples passing through 425 μm BS sieve in accordance with BS 1377 (1990). Each particle size distribution test was carried with 50 gm of oven-dried sample following standard procedures as stipulated in BS 1377 (1990). The Specific gravity of the soil was determined in accordance with BS 1377 (1990).

Compaction was done using British

(BSH) compaction in accordance with BS 1377 (1990) as well as West African standard compaction (WAS) in accordance with the Nigerian General Specification (1997). The West African standard compaction is identical to the British standard heavy compaction except that only 10 blows of the rammer per lift were applied rather than the usual 25 blows. This range of energy was selected in order to simulate the likely compaction energies encountered in the field (Daniel and Wu, 1993). The California Bearing Ratio (CBR) for shale samples with varying compactive energies of unsoaked and 4 day soaked samples were determined.

RESULTS AND DISCUSSION

Table 1 summarizes the results of index tests on samples 1 and 2 of Igumale soil. The results indicated that, the percentage of material passing through BS Sieve No 200 were 62.4 % and 58.4 %, plastic limit of 20.4 % and 29 %, liquid limit of 49 % and 54 %, and plasticity index of 28.6 % and 25 % respectively. The soil samples fall in group A - 7 - 6 soil by the AASHTO system of classification, and CL by Unified system of classification. Thus according to AASHTO classification, samples 1 and 2 are rated fair to poor subgrade materials while according to Federal Ministry of Works and Housing (1997) specification, samples 1 and 2 are not suitable for subgrade, subbase, and base materials as the percentage by weight finer than No. 200 BS test sieve were greater than 35 %. From the results of Atterberg limits of samples 1 and 2, the liquid limits were 49 % and 54 %, plastic limit of 20.4 % and 29 %, and plasticity index of 28.6 % and 25 % respectively. The linear shrinkage of samples 1 and 2 were 10.3 % and 13.2 % respectively. Federal Ministry of Works and Housing (1997) specification for road works recommended liquid limit of 50 % maximum, plasticity index of 12 % maximum and linear shrinkage of 8 % maximum for subbase and base materials. Both Samples 1 and 2 did not satisfy the specifications of liquid limit, plasticity index and linear shrinkage, except for sample 1 with liquid limit less than 50. However, sample 1 did not satisfy the specification of plasticity index and linear shrinkage; as such both samples 1 and 2 are not suitable for subbase and base materials.

Figure 1 shows the variation of dry density with moisture content for the three compactive energies, while Table 2 summarizes the compaction energies corresponding to the compaction test procedures. The maximum dry density (MDD) increased while optimum moisture content (OMC) decreased with increase in compactive energies from BSL compaction to WAS compaction then to BSH compaction. For example the MDD of samples 1 and 2 increased from 1.53 Mg/m^3 to 1.90 Mg/m^3 and 1.59 Mg/m^3 to 1.9 Mg/m^3, while the OMC decreased from 19.1 % to 14.3 % and 16.8 % to 13.0 % respectively. The increase in MDD and decrease in OMC with increase in compactive energies is in agreement with Proctor (1933), Craig (2004), Mustapha (2007) and Matawal (2009). According to O'Flaherty (1988), the range of values that may be anticipated when using the standard proctor test methods are: for clay, MDD may fall between 1.44 Mg/m^3 and 1.685 Mg/m^3 and OMC may fall between 20-30 %. For silty clay, MDD usually ranged between 1.76 and 2.165 Mg/m^3 and OMC between 8 and 15 %. Thus, looking at the results of the soil samples, it could be noticed that the samples are clay.

Table 3 shows the variation of unsoaked and soaked CBR with different compactive test procedures. The CBR values of samples 1 and 2 increased with increase in compactive energies of BSL compaction to BSH compaction. For example the unsoaked CBR increased from 16.3 % to 31.2 % and 30 % to 55 % for samples 1 and 2 respectively. The same trend was observed for the soaked CBR of samples 1 and 2, which increased from 3 % to 10.5 % and 2.5 % to 5.5 % respectively. Federal Ministry of Works and Housing (1997) specified that materials for subgrade, subbase, and base soils should attain minimum CBR values of 10 %, 30 %, and 80 %, respectively. From the CBR results, the unsoaked CBR of the two samples satisfied the condition of subgrade and subbase materials, but did not satisfy the specification of base materials.

Table 1: Index Test Results on Igumale Soil Samples.

Test	Sample 1	Sample 2
Liquid limit (%)	49	54
Plastic limit (%)	20.4	29
Plasticity index (%)	28.6	25
Liquidity index (%)	0.86	0.64
Linear shrinkage (%)	10.3	13.2
Specific gravity	2.62	2.53
Percentage passing 0.075mm sieve (%)	62.4	58.4
Depth (m)	1.5	1.5
Sand (%)	37.6	32.9
Silt (%)	24	25.5
Clay (%)	38.4	41.6
Maximum dry density (British standard light compaction) (Mg/m^3)	1.53	1.59
Optimum moisture content (British standard light compaction) (%)	19.1	16.8
Maximum dry density (West African standard compaction) (Mg/m^3)	1.80	1.71
Optimum moisture content (West African standard compaction) (%)	16.2	15.1
Maximum dry density (British standard heavy compaction) (Mg/m^3)	1.90	1.89
Optimum moisture content (British standard heavy compaction) (%)	14.3	13.0

Table 2: Compaction Energy for Corresponding Compaction Test Procedure

Test procedure	Weight of rammer (kg)	Height of fall (m)	Number of blows per layer	Number of layers	Compaction energy (kN/m^2)
British standard light compaction	2.5	0.3048	27	3	605.9
West African standard compaction	4.5	0.457	10	5	1,008.7
British standard heavy compaction	4.5	0.457	27	5	2,723.5

Table 3: Variation of Unsoaked and Soaked CBR with Different Compaction Test Procedures

Test procedure	Unsoaked CBR (%)		Soaked CBR (%)	
	Sample 1	Sample 2	Sample 1	Sample 2
British standard light compaction	16.10	10.1	3.0	2.5
West African standard compaction	31.2	30.5	5.5	2.8
British standard heavy compaction	40	37.5	10.5	5.5

CONCLUSION

The following conclusions can be made from the study. Igumale shale is silty clay and can be classified as an A-7-6 and CL soil by AASHTO and the Unified Soil Classification system respectively. Based on the results of the study, Igumale shale samples are rated as poor

There was improvement in the CBR and MDD of Igumale shale when the compactive energy was increased. This improvement was however not adequate for its use in road work. Therefore, the soil samples were found to be unsuitable for use as fill material at the three compactive energies used in this study. Chemical stabilization with higher compactive energy can

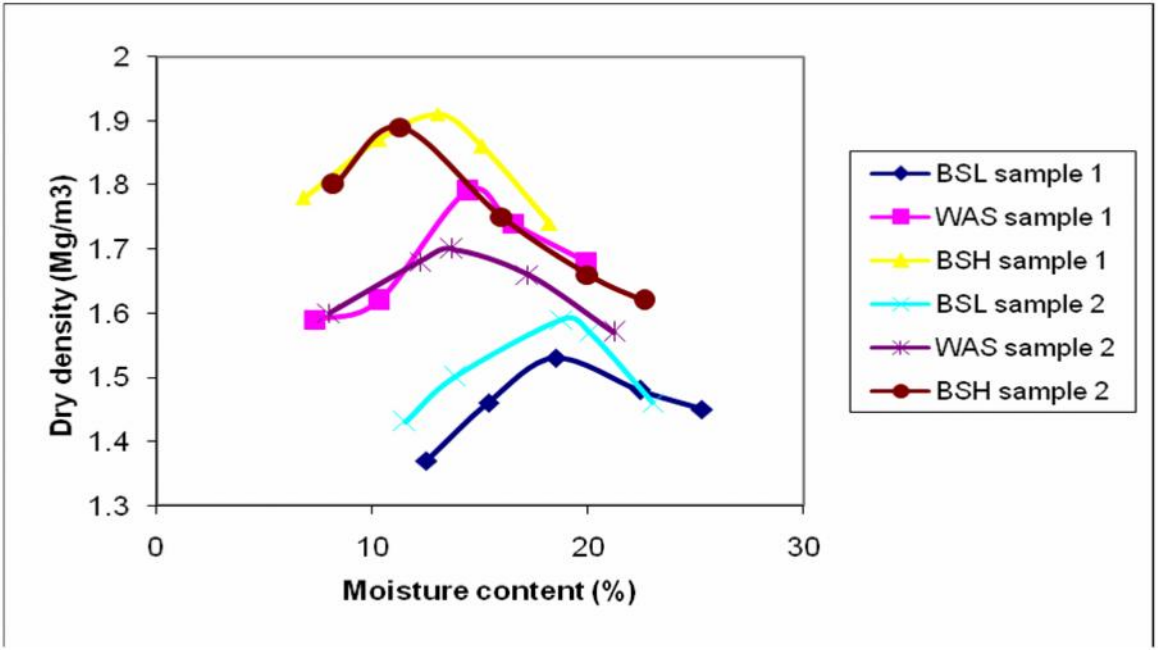

Figure 1: Variation of dry density with moisture content for the three compactive energies

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