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RESEARCH ARTICLE

HIGHWAY GEOTECHNICAL PROPERTIES OF QUARTZITE-DERIVED LATERITIC SOIL FROM IJEBU-IJESA, SOUTHWESTERN NIGERIA

Adeoye Aderemi Sunday[a*], Talabi Abel Ojo[a], Abubakar Hussain Olanrewaju[b], Adeniran Matthew Ademola[a], and Adejumo Temitope Kazeem[b]

[a]Department of Geology, Faculty of Science, Ekiti State University, Ado-Ekiti, Nigeria
[b]Department of Geophysics, Faculty of Physical Science, University of Ilorin, Ilorin, Nigeria
[*]Corresponding Author Email: aderemi.adeoye@eksu.edu.ng

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ABSTRACT

The highway geotechnical properties of quartzite-derived lateritic soil from Ijebu-Ijesa were investigated with a view to determining the suitability or otherwise for flexible highway construction.The field investigations included the study of the geological and geotechnical settings of the area and collection of four bulk samples within the study area. The laboratory investigation procedures involved the use of air dried sample which were subjected to laboratory classification tests including; grain size distribution and consistency limits (liquid limit and plasticity limit). Other engineering tests often employed in evaluating highway sub-grade material which include Compaction test, California Bearing Ratio (CBR) and Unconfined Compression test (UCS), in accordance with British Standard 1377 (1990) with some modification where necessary were also conducted. Results of engineering tests revealed that the specific gravity of the soil ranges from 2.32 to 3.10. The results of grain size distribution analysis revealed that the soil is well graded. The amount of fines of the soil samples range from 28.7% to 35.55%.The liquid limit for the soil samples ranges from 28.5% to 35.40%.Casagrande chart classification showed that the soil samples have low to medium plasticity. The maximum dry density ranges from 1850Kg/m^3 to 1890Kg/m^3 with their optimum moisture contents ranging from 13.08% to 17.98%. Unsoaked California Bearing Ratio of the soil ranges from 0.75% to5.3%.Unconfined Compressive Strength of the soil ranges from 132.18KN/m^2 to 135.00KN/m^2 and 1200.50KN/m^2 to 1640.92KN/m^{2}for uncured and cured respectively. Findings from this study indicate that the soil is suitable to be used as subgrade material in the construction of flexible pavement.

KEYWORDS

Flexible highway, geotechnical properties, lateritic soil,quartzite.

1. INTRODUCTION

Lateritic soils are reddish brown residual soils that are formed by chemical weathering of pre-existing soils such as granite, sandstone, shale and quartzite (Gidigasu, 1976; Okeke et al., 2013).They are commonly formed in tropical climatic regimes of the world (Amu *et al.*, 2011). Over 85 % of major oxides constituents of laterites are made up of SiO_2, Al_2O_3 and Fe_2O_3 (Adeyemi, 2002, Matheis and Pearson, 1982). The reddish brown colouration of these soils isdue to theirFe_2O_3 contents. Fe_2O_3 and Al_2O_3 are called sesquioxides and they constitute the cementitious materials of the laterites (Aguwa, 2013; Meigniem 1966). They are the most highly weathered soils in the classification system. The significant features of the lateritic soils are their unique colour, poor fertility, high clay content and lower cation exchange capacity (Tzu-Hsing, 2014).

Lateritic soils are widely used in the construction industry for road construction (highway sub-base and base course materials) and fills in dams, building foundations and levees (Simon *et al.*, 1973; Gidigasu, 1976). Lateritic soils in Nigeria have been found to develop on many rock types in different sub-climate and drainage environments. Each of the lateritic soils often exhibit unique set of physical, chemical and hence engineering properties. It is thus necessary that a comprehensive investigation be carried out on any lateritic soil prior to its utilization for any engineering purpose (Adeyemi, 2002, 2004).

The quality of laterites when used as road construction materials depend on the parent geologic formation (or rock) from which they were derived (Ehujuo et al., 2017). In this study, the geotechnical properties of some lateritic soils derived from quartzite in Ijebu-Ijesa area are determined and evaluated in terms of their suitability for road construction.

This study aims at assessing the geotechnical properties of a quartzite-derived lateritic soil for potential usage as subgrade material in flexible highway construction. The typical tests that are generally used to investigate soil proposed as subgrade material such as specific gravity, grain size distribution, Atterberg limits, compaction, California Bearing Ratio and unconfined compressive strength were conducted on the soil samples. If on the basis of these tests, the soils prove to possess properties desirable for a good subgrade material, then it should be considered as a suitable material for flexible highway construction.The outcome of this investigation is also expected to show the influence and importance of parent rock factor on the engineering properties of lateritic soil.

2. STUDY AREA

The study area is the Headquarters of Oriade Local Government area, Osun State, Nigeria. The area liesbetween longitudes 4° 46’ and 4° 56’ East of the Greenwich meridian and latitudes 7° 36’ and 7° 46’ North of the

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equator.The area is easily accessibledue to the availability of effective roadnetwork. The Ijebu-Ijesa/Esa-Oke Expressway on one hand and the presence of footpaths and untarredfeeder roads on the other links the study area. The sampling location is near Esa-Oke junction in Ijebu-Ijesa. Physiography or relief of the area is the result of the geomorphologic processes that have shaped the rocks of the area.The area has an undulating topography with an average elevation of 388 meters above the sea level.

This area is underlined by the ancient crystalline igneous and metamorphic rocks generally referred to as Pre-Cambrian Basement Complex (Rahaman, 1976). The rock found in the area belongs to Migmatite-gneiss-quartzite complex, a major rock suite of the Precambrian basement complex of southwestern Nigeria. The main rock unit in this area is quartzite. These rocks constitute the basement complex of Nigeria and they form part of the 700 - 459Ma mobile belt of West Africa. The studied soils are underlain by quartzite (Figure 1).

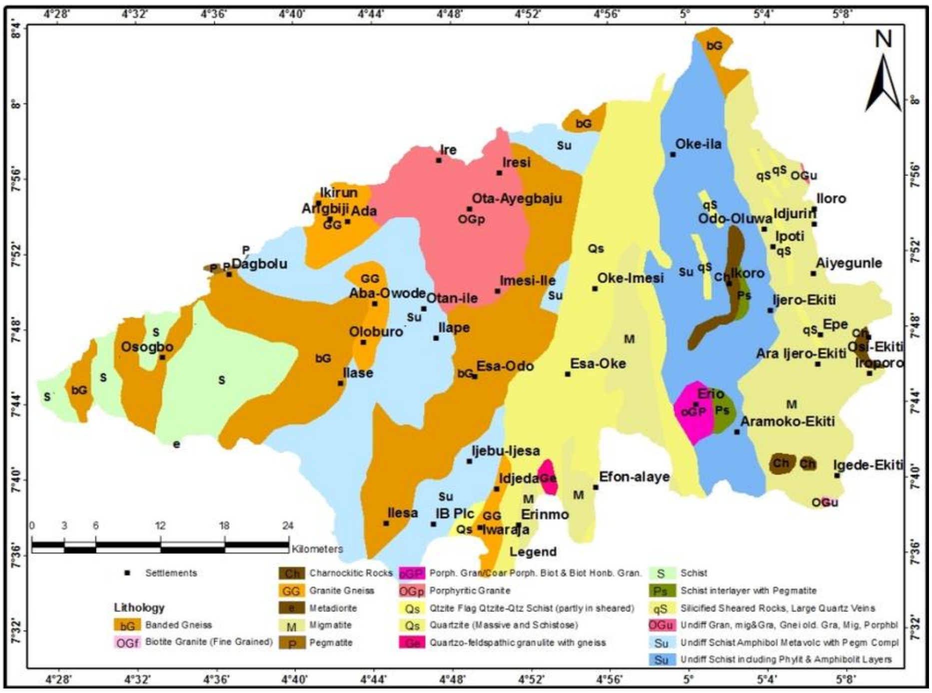

Figure 1: Geological Map of Osun and Ekiti State, showing the rock types present (Extracted from NGSA, 2006)

3. Materials and Methods

The materials used for this study was quartzite-derived lateritic soil.Four lateritic soil sampleswere obtained from borrow pits at four different locations aroundEsa-Oke junction area of Ijebu-Ijesa, These soils belong to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks.The samples were packaged in polyethylene bags, clearly labeled. The soil samples were oven-dried and broken into smaller fragments, care being taken not to reduce the sizes of the individual particles.

The field studies involved basic geologic mapping of the parent rock. It also entailed the examination of the soil profile exposed by road cuts. Bulk soil samples were taken at vertical intervals of 0.5m up to the depth of 2.0m since road construction activities rarely exceed this depth.The collected soil samples were subjected to geotechnical tests such as specific gravity, grain size distribution, plasticity, compaction, California Bearing Ratio and unconfined compression tests. The procedures employed in the determination of engineering properties were those stipulated in the British Standard 1370 (1990). Modifications of the geotechnical techniques were made where necessary. The grain size distribution analysis was done by wet sieving of samples soaked in about 2% calgon solution regularly agitated for a period of 24 hours.

4. Results and Discussions

Several limits have been proposed by various researchers with respect to the geotechnical propertiesof soil to be used as subgrade material. Such limits are presented here with the results obtained from this study.

4.1 Specific Gravity

From Table 1, the specific gravity of the soils ranged from 2.32 to 3.1. De-Graft Johnson (1969) observed that the specific gravity of lateritic soils falls within a range of 2.60 to 3.40.

4.2 Grain Size Distribution Analysis

Particle size analysis helps in determination of the size and percentage of coarse or fine grained materials needed to obtain a dense impermeable road pavement, and can also be used to estimate permeability of a soil. The result of particle size analysis is of great value when used for classification. The results of grain size distribution analysis revealed that the soil is well graded. From Table 1, the amount of fines of the soil samples range from 28.7% to 35.55%. According to the Nigerian government general specification of sub-grade soils required merits for roads and bridges recommends that soil to be used in road construction must not contain less than 12% fine (Federal Ministry of Works, 1994). General specification (FMWH, 1970), < 30% of fine material passes through 200 sieve is recommended to be useable as sub-base material. From Table 1,the percentage of fines (<0.075 mm) passing No. 200 BS sieve are less than 30 % for sample KAZ 2; but % fines are greater than 30 % for samples KAZ 1, KAZ 3, and KAZ 4. On the basis of Federal Ministry of Works (FMW) (1970) standard, only soils derived from sample KAZ 2 have acceptable % fines (<30 %). Soils derived from samples KAZ 1, KAZ 3, KAZ 4 have excess % fines that may reduce the strength of the compacted laterites (Matheis and Pearson, 1982; Singh, 2004).

4.3 Atterberg Limits

The liquid limit for the soil samples ranges from 28.5% to 35.40%. Casagrande chart classification (Figure 2) showed that the soil samples have low to medium plasticity. It classified KAZ 1, KAZ 2 and KAZ 3 as Medium Plasticity Clay and KAZ 4 as Low Plasticity Clay.

Table 1 shows that all the soil samples satisfy the FMW standard for liquid limit (<36 %). Low values of liquid limit and plasticity index in the soils are indications that the constituent clay mineral is the non-swelling kaolinite. When the liquid limits and plasticity index of the soils are high, there is the possibility that swelling clay mineral like montmorillonite, may be contained in the soil.Soils that have high plasticity characteristic have potential of constituting problem soils in highway construction.

4.4 Compaction characteristics

The maximum dry density ranges from 1850Kg/m^3 to 1890Kg/m^3 with their optimum moisture contents ranging between 13.08% and 17.98%. From Table 1, the maximum Dry Density values of all the soil samples used in the study are within the range expected for such soils when Standard proctor was used and they also satisfy the FMW standard (>1.76Mg/m^3). The maximum dry densities achieved in the laboratory exceed 1700Kg/m^3 in all the soil samples as shown in Table 1. They are therefore suitable for general filling and construction ofsubgrade and sub-base courses of roads.

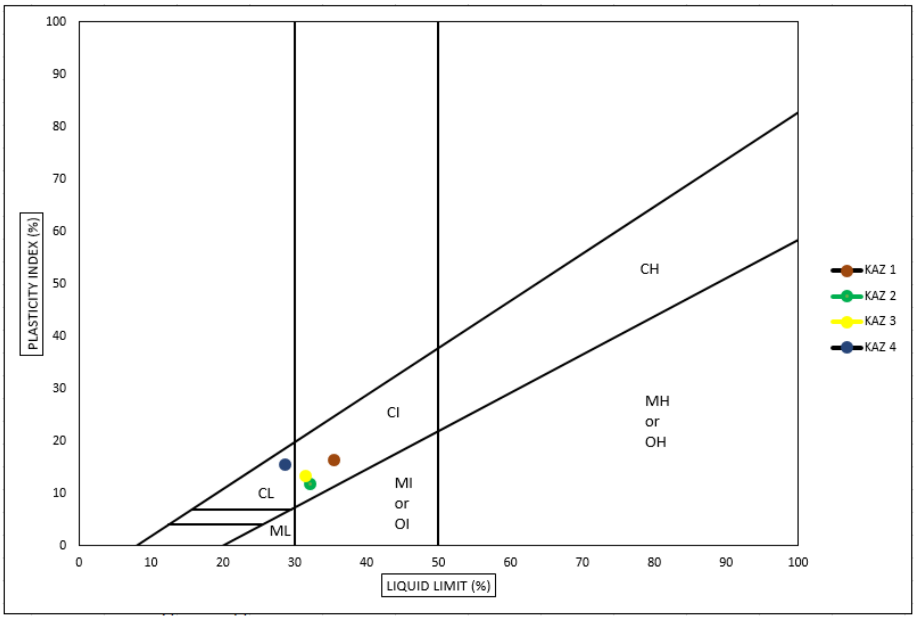

Figure 2: Casagrande Chart Classification of the Studied Soil Samples

Table 1: Summary Of Geotechnical Properties Of Quartzite-Derived Lateritic Soils

PARAMETERS		SAMPLE NO				Federal Ministry of Works Standards (1970)
		KAZ 1	K AZ 2	KAZ 3	KAZ 4	
Specific Gravity		3.1	3.1	2.4	2.32	-
% Fines (<0.075mm)		31.9	28.7	32.0	35.55	<30 %
% Sands(0.06 – 2mm)		23.89	22.07	19.65	35.80	-
% Gravel(>2mm)		44.11	48.93	48.20	42.55	-
Liquid Limit %		35.40	32.0	31.43	28.5	<36 %
Plastic Limit %		19.0	20.0	18.0	13.0	-
Plasticity Index %		16.4	12.0	13.43	15.5	<12 %
Max Dry Density(Kg/m³)		1890	1850	1850	1880	>1760 Kg/m³
Opt. Moisture Content %		16.53	13.08	17.98	13.21	-
CBR(Unsoaked)		0.75	4.0	2.7	5.3	<10%
Unconfined Compressive Strength(UCS)	Uncured	135.00	142.42	132.60	132.18	>103KN/m²
	Cured	1200.50	1504.64	1400.04	1640.92	>1034KN/m²

Table 2: Unconfined Compressive Strength of the studied soil samples

SAMPLE	NATURE OF SAMPLE	UCS(KN/m²)
KAZ 1	UNCURED	135.00
	CURED	1200.50
KAZ 2	UNCURED	142.42
	CURED	1504.64
KAZ 3	UNCURED	132.60
	CURED	1400.04
KAZ 4	UNCURED	132.18
	CURED	1640.92

4.5 California Bearing Ratio

California Bearing Ratio is often used in estimating the bearing capacity of highway subgrade and sub-base materials (Gidigasu, 1980). From Table 1, theunsoaked California bearing ratio value for the lateritic soil samples range from 0.75% to 5.3%. Theunsoaked CBR values (0.75-5.30) of the soils indicate that all the soil samples can be used for subgrade material in road construction because the values fall below 10% maximum stipulated by Federal Ministry of Works(1997).

4.6 Unconfined Compressive Strength

Unconfined Compression tests are used in estimating the bearing capacity of highway subgrade and sub-base materials.Unconfined Compressive Strengths of the studied soils are shown in Table 2. The valuesrange from132.18KN/m² to 135.00KN/m² and 1200.50KN/m² to 1640.92KN/m²for uncured and cured respectively. The obtained uncured strengths are generally higher than the minimum acceptable values of 103KN/m² while cured strengths are also higher than 1034 KN/m² recommended by the Central Road Research Institute of India reported by (De-Graft Johnson and Bhatia, 1969; Ola, 1977).The higher thecompressive Strength, the better the engineering soils.

5. Conclusion

This study reveals the highway geotechnical properties of quartzite-derived lateritic soils from Ijebu-Ijesa. The specific gravity of the soil ranges from 2.32 to 3.10. The results of grain size distribution analysis revealed that the soil is well graded. The amount of fines of the soil samples range from 28.7% to 35.55%. The liquid limit for the soil samples ranges from 28.5% to 35.40%. Casagrande chart classification showed that the soil samples have low to medium plasticity. The maximum dry density ranges from 1850Kg/m³ and 1890Kg/m³ with their optimum moisture contents ranging between 13.08% and 17.98%. Unsoaked California Bearing Ratio of the soil ranges from 0.75% and 5.3%. Unconfined Compressive Strength of the soil ranges from 132.18KN/m^2 to 135.00KN/m^2 and 1200.50KN/m^2 to 1640.92KN/m^{2}for uncured and cured respectively. Findings from this study indicate that the soil is suitable to be used as subgrade material in the construction of flexible pavement.

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