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Characterisation of Index Properties of Lateritic Soils in Ado Ekiti South Western, Nigeria

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Abstract: ***The aim of this research is to evaluate the index properties of lateritic soils in Ado Ekiti Area of Ekiti State, Nigeria. The areas were divided into Six Zone with a total of eighteen samples with three samples per zone. Laboratory test such as: Natural Moisture Content (NMC) , Specific gravity, Grain size analysis, Liquid Limit , Plastic Limit, Linear Shrinkage, All the test were carried out in accordance with the British Standard code of practice (BS1377:1990). The visual soil profile description of all trial pits investigated, reveal little variation within the soil strata. The laboratory results indicated that the particle size gradation for gravel ranged from 1 to 44 %, sand ranged from 26 to 77% and fines ranged from 8 to 46%; natural moisture content ranged from 1.1 to 18.7%; specific gravity ranged from 2.23 to 2.79; the bulk density ranged from 1134. to 1625. kg/m3, ; the liquid limit ranged from 25 to 65%, plastic limit ranged from 17 to 43%, plasticity index ranged from 10 to 30%; linear shrinkage ranged from 3.6 to 15.5%;AASHTO and USCS soils classification system classified the soils as follows for all the six zone investigated : A-2-4, A-2-6, A-6 , A-7-5 for (AASHTO) and CL, MH and CH materials which describe the materials as Silty gravelly sandy soil, Clay of low Compressibility and Clay of High Compressibility. They satisfy Nigeria Specification for Road and Bridges requirements for subgrade, sub base and base course materials. Zone 6 and Zone5will be suitable only for base course, sub base course, earth dam and fills except for Zone 3that are classified as unsuitable materials while other Zones will be considered suitable for sub grade materials. This research work has provided information for engineers and contractor for the use of these lateritic soils materials for construction work and has prevented possible delays and additional expenses during construction due to inadequate geotechnical data within this region. It is recommended that all contractors should ensure that the testing and quality control of lateritic materials on project site within this area is done before the commencement of work.***

Keywords: Linear shrinkage, plasticity index, subgrade, index properties, soil profile

1. Introduction

Soil index properties are the properties of soil that help in identification and classification of soil. These are properties of soil that indicate the type and conditions of the soil and provide a relationship to structural properties. Soil index properties are used extensively by engineers to discriminate between the different kinds of soil within a broad category (ELE, 2013).A good knowledge about a site including its subsurface conditions is very important in its safe and economic development. It is therefore an essential preliminary to the construction of any civil engineering work such as roads, buildings, dams, bridges, foundations, etc., (Adeyeri 2015).It is unfortunate to note that in developing countries like Nigeria only few investors in the construction industry take time to execute subsoil investigation prior to commencement of construction activities on their projects. The result is the calamitous consequences such as failure or collapse of buildings and other massive engineering structures which often cause untold hardship and damage and sometimes even loss of lives and properties. Many attempts have been made of recent to study the geotechnical properties of soils around Ekiti State in Southwestern Nigeria (Bayowa et al., 2014, Okunade, 2007; Oladapo and Ayeni, 2013; Owolabi and Aderinola, 2014; Talabi et al, 2013; Adeyeri et al, 2017. However, no previous attempt has been made to investigate the index properties of lateritic soil sequence in Ado Ekiti area of Ekiti State, Nigeria. Hence reason for this research arises to evaluate the soil index properties for the purpose of soil characterization of Ado Ekiti area lateritic soils of Ekiti State, Nigeria. (This will subsequently consolidate the data requirement for a web-based geotechnical database management system for Nigerian soils as proposed by Okunade (2010). Laterite as products of tropical weathering with red, reddish brown, or dark brown color, with or without nodules or concreting and generally (but not exclusively) found below hardened ferruginous crust or hard pan (Ola, 1983). The aim of this research is to determine the index properties of lateritic soil in Ado Ekiti local Government area, Southwestern Nigeria.

2. Local geology of the Study Area

The study involves collection of soil samples from borrow pits in Ado Ekiti using the method of Undisturbed and disturbed sampling. The areas are as shown in figure: 1) lies on latitude 7o15′North of the Equator and on longitude 5o15′east of the Greenwich Meridian. It stands on the altitude of about 370 meters above the sea level. The study area occurred within the Pre – Cambrian crystalline rocks of the Basement complex of Southwestern Nigeria (Rahamam, 1976). The predominant rock types in the study area are, Charnockites, granite gneiss and migmatitic rocks. The samples were taken at a depth of 1.1m from the surface.

2.1. Location map of the study area:

Figure 1: Map of Ekiti State showing Ado Ekiti Town (Oladipo et al, 2013)

3. Material and Methods

3.1 Sampling

The samples used for the analysis were collected from eighteen (18) different locations within the area (Fig. 1). A disturbed method of sampling was employed in collecting the samples. Care was taken when collecting the samples to ensure that the analyzed samples are true representatives of the insitu materials. The samples were excavated with the Help of a hoe and a shovel. The samples were packaged in polyethylene bags, clearly labelled and sent to the geotechnical laboratory of the federal polytechnic Ado-Ekiti, South Western Nigeria for relevant laboratory tests.

3.2 Laboratory Test

The following laboratory tests were conducted on the samples: Atterberg limits test, specific gravity test, sieve analysis test, hydrometer test, bulk density and natural moisture content test, prior to preparing the test specimens, the materials were oven-dried and broken into smaller fragments, care being taken not to reduce the sizes of the individual particles.

3.3 Particle Size Gradation

This test was carried out in accordance with wet sieving BS 1377 [1990] test 7a standard. The British Standard (BS) Sieves used, adequately covered the range of aperture size for the soil. A 2 mm sieve was nested in a 63 micron sieve without the lid. The soil was placed little at a time on the 2mm sieve and washed on a sink with a jet of clean water. The whole of the material retained on each sieve was allowed to drain and then carefully transferred to a tray and placed in the oven to dry at temperature of 105 to 110°C overnight. The dry soil was then passed through a nest of the complete range of sieves to cover the size of particles present down to 63µmsieve. The operation was carried out on a mechanical sieve shaker. The Percentage Weight retained and the Percentage Passing in the sieves were determined. The percentage passing was then plotted against sieves numbers (see figure….).

3.4 Natural Moisture Content

This test was carried out in accordance with BS 1377 [1990], test 1 A standard. A sample container was weighed to 0.01gand the weight was recorded as m1. The soil material to be tested was then added, both container and soil were weighed and the value was recorded as m2. The container with sample was then placed in the oven for 24 hours at a controlled temperature of 105°C, after which it was transferred to the desiccators to cool. The oven dried and cooled sample was the weighed and the value recorded as m3. The Natural Moisture Content was then determined as weight of water over weight of dry soil.

3.5 Specific Gravity

This test was carried out in accordance with BS 1377 [1990] standard. Three density bottles were washed, dried, cooled and weighed to the nearest 0.001g and recorded as (W1).Sample of appropriate mass (50 to 150g) was obtained by quartering down the original sample after passing a 2 mm BS sieve. Each bottle with the soil was weighed and recorded as(W2). Distilled water was added to each bottle so that the soil was covered and the bottle half full. The soil, bottle and water was weighed and recorded as (W3). The bottles were cleaned out and filled completely with distilled water and placed in the constant temperature bath until attainment of bath temperature. The bottle and distilled water was weighed and recorded as (W4).The specific gravity, Gs was calculated as = (W2-W1) / (W4-W1) - (W3-W2).

3.6 Bulk density

These tests were carried out in accordance with BS 1377 [1990] test 16 standard. Bulk and dry densities are fairly easy determinations, which yield valuable insight on a soils potential to support a structural foundation. These parameters were determined using soil cores. A hollow cylinder provided with a cutting edge was forced into the ground, then retrieved with a column of soil, preserved and taken to the laboratory where it was extruded into a cylindrical mould with a known mass and volume. It was weighed and the mass recorded. The moisture content was then determined as per (3). The bulk density was determined by dividing the mass of wet soil by the volume of the cylindrical mould while the dry density was determined as follows: Dry density, (ρd) = ρb x100/100 + m where, ρb = bulk density and m= moisture content (%).

3.7 Atterberg Limits Test

The determination of liquid limit was carried out in accordance with American Society of the International Association for Testing and Materials (ASTM) methodD423 standard. About 250 g of soil sample from thoroughly mixed portion of soil material, passing 0.425 mm was placed\ in a porcelain dish and mixed with 15 to 20 ml distilled water by alternately and repeatedly stirring, kneading and chopping with spatula. Further water increment of 1 to 3 ml was added and the process repeated until sufficient water has been thoroughly mixed with the soil. A portion of the mix was pressed into the cup using a spatula and carefully spread into position while avoiding entrapment of air bubbles. The liquid limit was taken as the moisture content corresponding to 25blows. Similarly, for plastic limit determination, the test was carried out in accordance with BS 1377 [1990] test

3 standard .About 20 g of soil sample, passing 0.425 mm sieve was used for the test. The sample was thoroughly mixed with distilled water and kneaded for about 10 minutes to form a plastic ball. The ball was molded between the fingers and rolled between the palms, such that the warmth from the hand slowly dried it. The thread was then rolled between the fingers and a glass plate using steady pressure which reduced the diameter to about 3mm, the pressure was maintained until the thread crumbled. This crumbling point is the plastic limit.

3.8 Linear shrinkage test

This test was carried out in accordance with BS 1377 [1990] test 5 standard. About 150 g of air dried soil passing 0.425mm sieve was used. The mould was cleaned, dried and a thin film of silicone grease was applied to the inner surface to prevent soil sticking to the mould. The soil was placed on a glass plate and mixed properly using distilled water for about10 minutes until a homogenous paste of about the liquid limit was achieved. The length of the bar of soil was measured using a venire caliper, both top and bottom surfaces. The mean of the two lengths was taken as the dry length.

4. Results and Discussion

4.1 Natural Moisture Content

Table 1 shows the results of natural moisture content of the soils in all the trial pits investigated which varied between 1.1 and 19.2%. The values are fairly high considering the time of test, indicating the soil potential for water retention, a property of fine grains.

4.2 Grain size analysis:

The graph of grain size analysis performed on all the trial pits investigated. Many of the samples had a very high percentage finer than 0.0075 fractions that is >35% varied between 13 and 30% for (Zone 6and part of Zone 3 samples), 35-36% for (Zone 5, and part of zone 4) & 42-78% for (Zone1, Z3S2, and Zone 3) respectively. Hence, the soils are describe as Silty gravelly sandy soils for (Zone 6and Zone 3 samples) while other location investigated were Clay of high compressibility respectively.

4.3 Consistency limit test:

Table 1 shows the results of liquid limit (LL %), and plasticity index (PI %) evaluated on all the trial pits, which varied between17-65% and 10-30% respectively. It was observed that soils from (Zone 6 and Zone 3 samples) has their liquid limit (LL %), and plasticity index (PI %) ranges between 17-37% and10-12% respectively while Zone5, Zone4, Zone1 and Zone 3) varied between 35-65% and 11-30%.. Federal Ministry of Works (FMW) general specification requirements for roads and bridges (1994) recommend liquid limit not greater than 80% for sub-grade and not greater than 35% for sub-base and base course. Also, plasticity index not greater than 55% for sub-grade and not greater than 12% for both sub-base and base. From the examined soil samples, the soils fall within these specifications, except for poly and Abuad that fell out of maximum specified. Thus making other location suitable for sub-grade, sub-base and base course and earth fill materials.

Table 1: Results of the soils index properties

Samples Zones		NMC%	GS	LL%	PL%	PI%	SL%	%Passing			Soil Classification Systems	
								0.075 (mm)	0.6 (mm)	2(mm)	AASHTO	USCS
1	**ZIS1**	15.8	2.23	58	28	30	05	58.5	94	78	A-7-5	CL
	Z1S2	14.9	2.59	30	18	12	06	45.5	92	71	A-6	CL
	Z1S3	19.2	2.61	65	37	28	10	78.4	100	98	A-7-5	MH
2	**Z2S1**	16.8	2.46	60	27	18	06	64.1	99	94	A-7-5	MH
	Z2S2	13.7	2.79	53	33	19	10	44.0	56	72	A-7-5	MH
	Z2S3	11.6	2.39	52	30	22	10	48.0	76	63	A-7-5	CH
3	**Z3S1**		2.56	43	21	22	09	42.0	100	87	A-7-5	CL
	Z3S2	4.8	2.54	53	27	26	11	47.0	99	85	A-7-5	CH
	Z3S3	1.1	2.60	37	25	12	07	29.3	98	73	A-2-4	CL
4	**Z4S1**	12.7	2.36	50	28	22	07	43	75	80	A-7-5	OL/ML
	Z4S2	18.7	2.30	43	12.5	31	7.7	61	70.2	96.2	A-7-5	CH
	Z4S3	16.7	2.29	50	30	20	9.8	41	78	83	A-7-5	ML
5	**Z5S1**	10.5	2.44	50	31	20	15.5	35	65	80	A-2-6	OH
	Z5S2	12.2	2.41	35	21	14	05	36	76	85	A-2-6	CL
	Z5S3	15.9	2.31	52	43	11	10	44	62	80	A-7-5	MH
6	**Z6S1**	10.7	2.57	35	25	10	3.6	25	68	79	A-2-4	ML
	Z6S2	9.5	2.33	25	15	10	4.9	20	60	75	A-2-4	CL
	Z6S3	8.2	2.66	27	17	10	05	13	39	58	A-2-4	CL

Table 2: Showing Soil Profile and General Strata Description

Sample Zones	From Depth Ranges (meters)	To Depth Range (meters)	Strata Description
ZIS1	0	1.1	Reddish brown, Indorated and multled , Iron oxide mixed with Quartz grains
Z1S2	0	1.1	Greyish, Indorated and multled , Iron oxide mixed with Quartz grains
Z1S3	0	1.1	Greyish, plastic and indurated, more of clay mixed with little pocket of iron oxide
Z2S1	0	1.1	Brownish, granular-indorated, Quartz mixed with organic matter
Z2S2	0	1.1	Redish brown Non- indurated publish Iron stone, Quartz
Z2S3	0	1.1	Reddish brown, Non- indurated peblish granular quartisitic pebbles
Z3S1	0	1.1	Dark greyish Sandy in appearance, non indurated, - iron oxide mixed with dirty Quartz
Z3S2	0	1.1	Dark greyish brown, fine sandy and non indurated, iron oxide mixed with dirty Quartz
Z3S3	0	1.1	Reddish brown, Sandy Quartz, iron oxide and clay
Z4S1	0	1.1	Greyish, plastic and indurated, more of clay mixed with little pocket of iron oxide.
Z4S2	0	1.1	Reddish brown, Non- indurated peblish granular quartisitic pebbles
Z4S3	0	1.1	Redish brown Non- indurated publish Iron stone, Quartz
Z5S1	0	1.1	Brownish, granular-indorated, Quartz mixed with organic matter
Z5S2	0	1.1	Dark greyish Sandy in appearance, non indurated, - iron oxide mixed with dirty Quartz
Z5S3	0	1.1	Redish brown Non- indurated publish Iron stone, Quartz
Z6S1	0	1.1	Brownish, granular-indorated, Quartz mixed with organic matter
Z6S2	0	1.1	Dark greyish Sandy in appearance, non indurated, - iron oxide mixed with dirty Quartz
Z6S3	0	1.1	Redish brown Non- indurated publish Iron stone, Quartz

5. Conclusion

The characterization and index properties of lateritic soils in Ado-Ekiti of Ekiti State Capital have been evaluated. Trial pits were excavated and samples of undisturbed soil were obtained for laboratory tests. The results of the tests reveal the following: most of the pits has percentage of fine greater than 40%, except few location which has percentage fines less than 35%. Ground water was not encountered. The soils sample were grouped as (CH, MH, and CL) and A-2-4, A-2-6, A-6 and A-7-5 respectively. This classifies the soils as Clay of high compressibility, Clay of medium to high compressibility and Clay of low compressibility. The lateritic soils are suitable as dam, earth fill, subgrade, sub base and base course materials in civil engineering construction project. It is recommended that all contractors should ensure that the testing and quality control of lateritic soil materials is done before the commencement of earthworks on site and the adequate quality of construction as the construction project is being executed.

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