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Characterization and Classification of Geotechnical Index Properties of Shallow Soil Deposits at Oworoshoki Area, Kosofe Local Government, Lagos, Nigeria

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ABSTRACT: The study of geotechnical index properties of soils in Oworoshoki, Kosofe, Lagos State was conducted to characterize and classify the index properties of soil samples. Disturbed and undisturbed soils were collected at different shallow depths (1m, 2m and 3m) from the study area and laboratory test was conducted. The laboratory test conducted includes natural moisture content, atterberg limits (liquid limit and plastic limit), particle size distribution, specific gravity, unit weight and hydrometer. The results of the test were gotten: natural moisture content as 23.5%, 24.5% and 25.3% , liquid limits (LL) 28.68%, 26.64% and 29.10%, Oworoshoki is non-plastic for the three depths i.e. plastic limit (PL) is 0, particle size distribution percentage passing through BS #200 (0.075mm) are 95.97 %, 97.97%, 98.10% and this shows that the soil sample contain much silt, the samples are non-plastic for all depths (1m, 2m and 3m), specific gravity as 2.61, 2.55 and 2.60, unit weight as 17.5 KN/m^3, 18.1kn/m^3 and 18.9KN/m^3 and hydrometer percentage passing through BS #200 (0.075mm) as 95.97% at 1.0m depth, 97.97% at 2.0m depth and 98.10% at 3.0m depth. Hydrometer test was conducted because 95.97% passes sieve 0.075mm.This shows that the soil contain high amount of silt. Soils from depth 1.0m, 2.0m and 3.0m are non-plastic (NP) because the Plastic Index (PI=0) and the soil samples are classified as A – 3 according to American Association of State Highway and Transportation Officials (AASHTO) System.

KEYWORDS: Soil samples, natural moisture content, Atterberg limits, particle size distribution, specific gravity.

INTRODUCTION

Oworoshoki is an area found in Kosofe local government in Lagos State. Lagos State is located in the western part of Nigeria. It shares boundaries with Ogun State both in the north and east and is bounded on the west by Republic of Benin. In the south, it stretches for 180km along the coast to the Atlantic Ocean. It occupies an area of 3,577km^2. It falls on latitude 6^{0}27'10.8''N and longitude 3^{0}23'44.99''E. Characterization and classification of geotechnical index properties of the soil are essential to define its main potentials and restrictions. Index properties of soil are these properties of soil that indicate the type and condition of the soil and provide a relationship to structural properties. It can also be define as properties which facilitate identification and classification of soils for engineering purposes. This study is only concern with these index properties and characterizing it. Generally, index properties of soils are determined by laboratory testing on soil samples obtained from the site (Yoon *et al.*, 2015). The relationship between all engineering infrastructure and their foundation soil is too important to be ignored. A considerable increase in soil utility for engineering works is expected as the country aspires toward improving infrastructural development. Incessant occurrence of road pavement failure and building collapse has made it imperative for proper understanding of the geotechnical properties of soils. Lack of geotechnical information has result the collapse of some buildings in Lagos State, Oyo State, Anambara State, Plateau State etc of Nigeria between 2018 and 2019. Expansive soil cause significant damage to structure and roadways by cyclic shrink-swell within the active zone of soil (Christodoulias, 2015).Expansive soils cause billions of dollars of damage to homes and property each year (Christodoulias, 2015).The significance of swelling soils in relation to geotechnical problems is now widely recognized. Geotechnical problems arising from expansive unsaturated soils are well demonstrated by many case histories all over the world, especially in geographical zones having arid, semi-arid and tropical climatologically conditions (Christodoulias,2015).The existence of specific expansive minerals in the clay soil related to the climatologically conditions, seasonable variation of rainfall precipitation (wet and dry periods) and fluctuation of water table in Mediterranean countries, has resulted to induce unexpected shrinkage and swelling movements with all the unfavorable consequences. It was observed that light industrial structures and small buildings suffer from heaving, road pavements to develop shrinkage cracks, canal lining and low embankments resting on swelling soil or embankments constructed with swelling soil, suffer distortion and cracking. If the propensity of a soil to shrink and swell is known before construction, shrinkage limit results can give information to design engineers, because if it is known the ability of soil to shrink or swell before construction, damage can be avoided. Geotechnical properties of soils influence the stability of civil engineering structures. The civil engineering structures like building, bridge, highway, tunnel, dam, tower, etc. are founded below or on the surface of the earth (Surendra, 2017). For their stability, suitable foundation soil is required. To check the suitability of soil to be used as foundation or as construction materials, its properties are required to be assessed (Laskar and Pal,2012).Clay is predominant in most of the sub grade soils of Nigeria. Due to the relative abundance of these soil and ease of acquisition they have wide application in engineering construction works (Oyediran, 2011). Identification and classification can only be achieved through atterberge limit test (determination of liquid limit, plastic limit and linear shrinkage), specific gravity of soil particles, particle size distribution etc. For engineering purpose, soil is defined as any loose sedimentary deposit such as gravel, sand, silt, clay or mixture of these materials (smith, 1994). It is made up of various size of particles parked together with spaces between the particles known as voids. The voids are generally the mixture of air and water. A whole of laboratory test can be performed on soils to measure a wide variety of soil properties. Some soil properties are intrinsic to the composition of the soil matrix and are not affected by sample disturbance, while other properties depend on the structure of the soil as well as its composition, and are tested on relatively disturbed samples (Rorome and Ekeocha, 2015).Some soil test measure direct properties of the soil, while others measures index properties which provide useful information about the soil without direct measuring of the property desired (Rorome and Ekeocha, 2015). The previous work done in this area was also carried out by Akpokodje (1989; 2001) where he investigated the soil properties and pavement performance in the Niger Delta; the incidence of pavement failure of various roads in the Niger Delta, and correlated this with various factors such as rainfall, grain size distribution.(Rorome and Ekeocha, 2015) have conducted a study on geotechnical index properties of soil from various locations in Warri, Delta State. From his laboratory test results; Moisture Content (MC) ranges from 8.1- 26.9%, Liquid Limit (LL) ranges from 22.0 - 38%, Plasticity Limit (PL) ranges from 19.5 - 22.4% and Plastic Index (PI) ranges from 2.1-17.9%. He observed that the sample collected from the locations contain high percentage of fine soil (silt clay and fine sand) without gravel sized particles which was classified based on Unified Soil Classification Schemes (USC) as poorly graded, well drained, intermediate plasticity and medium swelling potential soil since it does not contain particles of all sizes. (Oke and Amadi, 2008; Nwankwoala and Warmate,2014) have highlighted that, assessment of geotechnical properties of subsoil at project site is necessary for generating relevant input data for design and construction of foundations for the proposed structures. Oghenero *et al* (2014) have stated that proper design and construction of civil engineering structures prevent an adverse environmental impact or structural failure or post construction problems. Information about the surface and sub-surface features is essential for the design of structures and for planning construction techniques. For complex projects involving heavy structures, such as bridges, dams, multi-storey buildings, it is essential to have detail exploration. The purpose of detailed explorations is to determine the engineering properties of the soils for different strata (Arora, 2008). Lack of understanding the properties of the soil can lead to the construction errors. The suitability of soil for a particular use should be determined based on its engineering characteristics and not on visual inspection or apparent similarity to other soils. The loading capability of soil depends upon the type of soil. Generally, fine grained soils have a relative smaller capacity in bearing of load than the coarser grained soils (Jain *et al*., 2015).Plasticity index and liquid limit are the important factors that help an engineer to understand the consistency or plasticity of clay (Surendra, 2017).

MATERIALS AND METHODS

Shallow soil samples (disturbed and undisturbed) at different depths (1m, 2m and 3m) were collected from the study area. The disturbed samples were collected using hand trowel, digger, hoe and polythene bags while the undisturbed samples were collected using short pipes (samplers) by stroking each pipe into the ground completely to the level of the depth with a hammer. They were removed, wrapped and labeled for identification then put into a polythene bag which is airtight to maintain moisture content before laboratory test. The two samples were used for determining natural moisture content, specific gravity, sieve analysis, Atterberg limits and unit weight in the laboratory. Global Positioning System (GPS) was used to locate the coordinate of the site. American Association of State Highway and Transportation Officials (AASHTO) system was the method of soil classification used for classifying the soil sample.

Study Area

Oworoshoki area, Kosofe local government: It falls on latitude $6^{0}\ 27^{'}$ 10.8''N and longitude $3^{0}23^{1}$44.99''E, 12km from Lagos. The study area is as shown with an arrow indicating in Plate1 bellow.

Plate 1: Map of Lagos State showing the Study Area

RESULTS AND DISCUSSION

Natural Moisture Content

Table 1 below shows the Natural Moisture content of sample at 1m, 2.0m and 3m depth.

Table 1 Natural Moisture content of sample at 1.0m, 2.0m and 3.0m depth

Depth (m)	1.0	2.0	3.0
Can No.	A1	C16	B4
Weight of empty can (g) =W1	10.2	10.4	10.61
Weight of can + wet sample =W2			
Weight of can + dry sample =W3			
Weight of wet sample W4 = (w2-w1)			
Weight of dry sample W5= (w3-w1)			
Weight of water			
W6 = (w4-w5) Moisture content W = W6/W5 x100	23.5	24.5	25.3

Figure 1. shows the Natural Moisture Content Graph of moisture content against depth of sample at 1.0m, 2.0m and 3.0m depth.

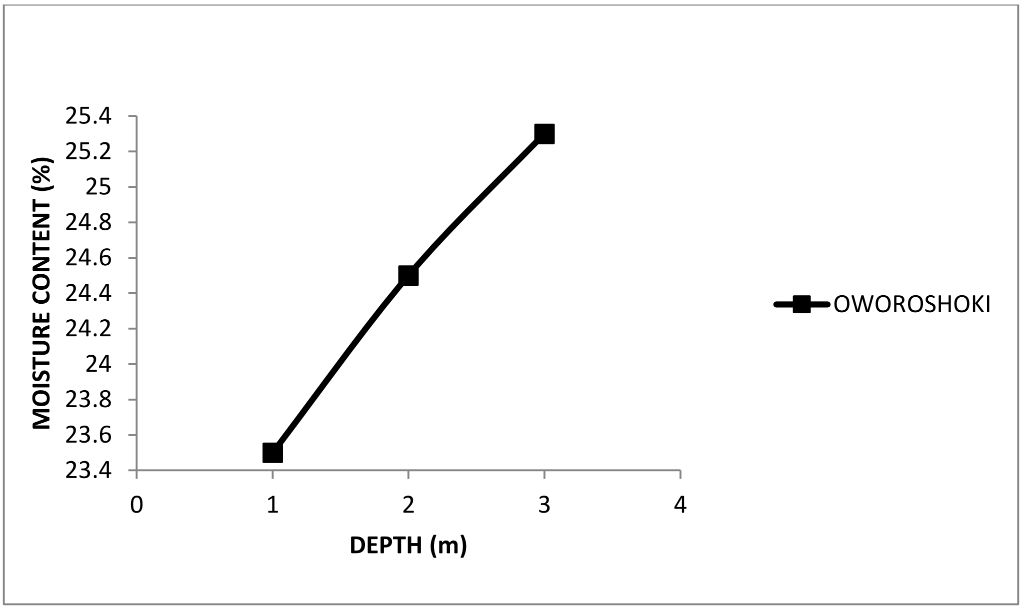

Figure 1: Natural Moisture Content

Atterberg Limits

Table 2, 3 and 4 below shows Liquid limit cone penetrometer method at 1m, 2.0m and 3m depth respectively.

Table 2. Liquid limit cone penetrometer method at 1.0m depth

	Liquid Limit						Plastic Limit
Con No	1	2	3	4	5	1	2
Penetration	3.9	8.8	12.5	18.7	22.5		
Can weight	37.95	37.75	37.60	37.36	37.58		
Weight of can +wet soil	58.26	63.21	60.69	62.71	58.2		
Weight of can +dry soil	55.04	58.54	55.98	57.24	53.51		
Weight of moisture	3.22	4.67	4.71	5.47	4.71		
Weight of dry soil	17.09	20.79	18.38	19.88	15.93		
Moisture content	18.84	22.46	25.63	27.52	29.57	0.00	0.00
Liquid Limit	28.68	%	Average	Plastic	Limit	0.00	0%

Table 3. Liquid Limit cone penetrometer method at 2.0m depth

	Liquid Limit					Plastic limit	
Can No	1	2	3	4	5	1	2
Penetration	5.6	10.7	15.2	19.0	23.2		
Can weight	37.21	38.55	37.75	38.03	37.68		
Weight of can +wet soil	38.33	66.72	66.86	64.63	67.40		
Weight of can +dry soil	54.93	61.56	61.19	59.07	60.92		
Weight of moisture	3.40	5.16	5.67	5.56	6.48		
Weight of dry soil	17.72	23.01	23.44	21.04	23.24		
Moisture content	19.19	22.13	21.19	26.13	27.88	0.00	0.00
Liquid limit	26.64%		Average plastic limit			0.00%	

Table 4. Liquid limit cone penetrometer method at 3.0m depth

Can No	1	2	3	4	5	1	2
Penetration	4.7	9.8	13.9	18.6	23.0		
Can weight	37.46	37.96	37.42	37.40	37.79		
Weight of can +wet soil	58.58	53.65	55.73	58.09	71.68		
Weight of can +dry soil	55.34	58.94	59.87	51.32	53.83		
Weight of moisture	3.24	4.71	5.86	6.77	7.85		
Weight of dry soil	17.88	20.98	22.45	23.92	26.04		
Moisture content	18.12	22.15	26.10	28.30	30.15	0.00	0.00
Liquid limit	29.10%		Average plastic limit			0.00%	

Figure 2, 3 and 4 shows the Liquid Limit (LL) graph of penetration against moisture content at 1.0m, 2.0m and 3.0m respectively.

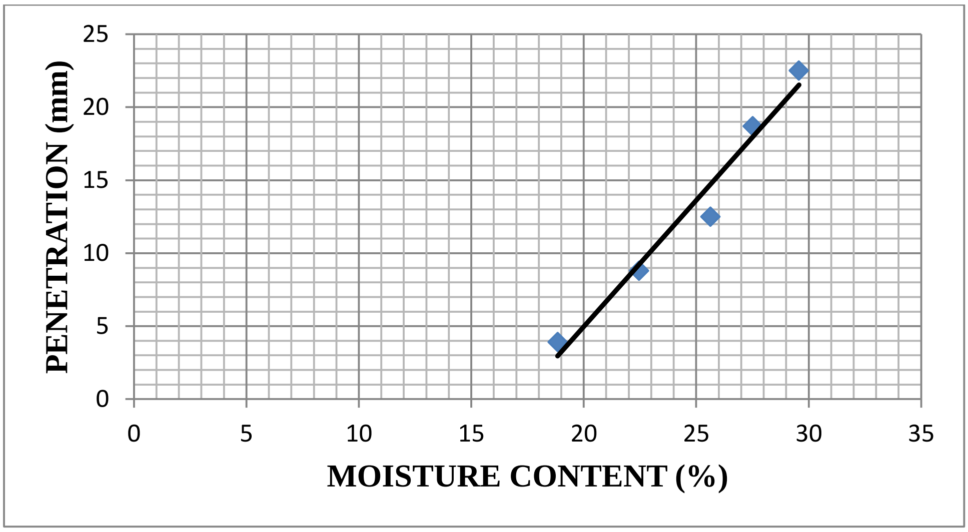

Figure 2: Liquid Limit at 1.0m

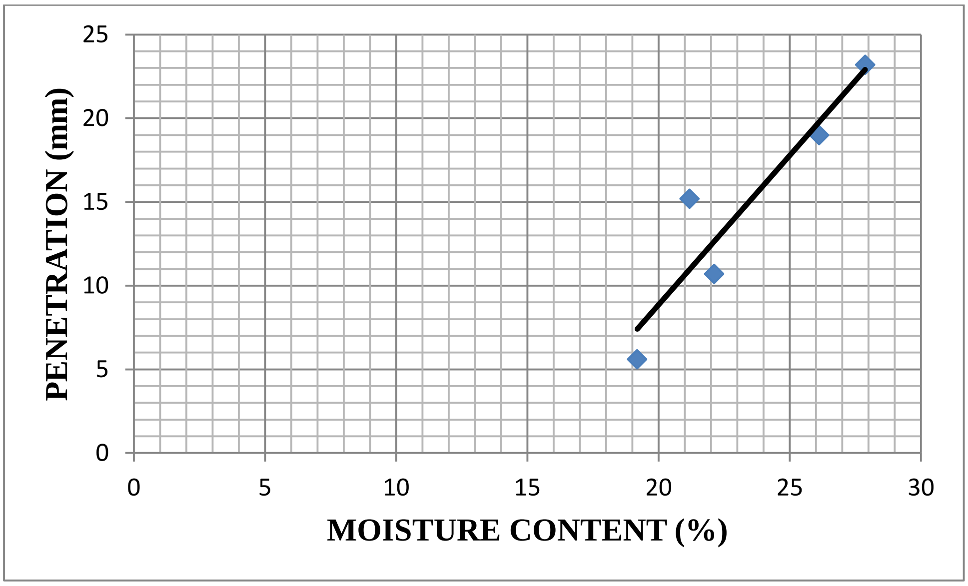

Figure 3: Liquid Limit at 2.0m

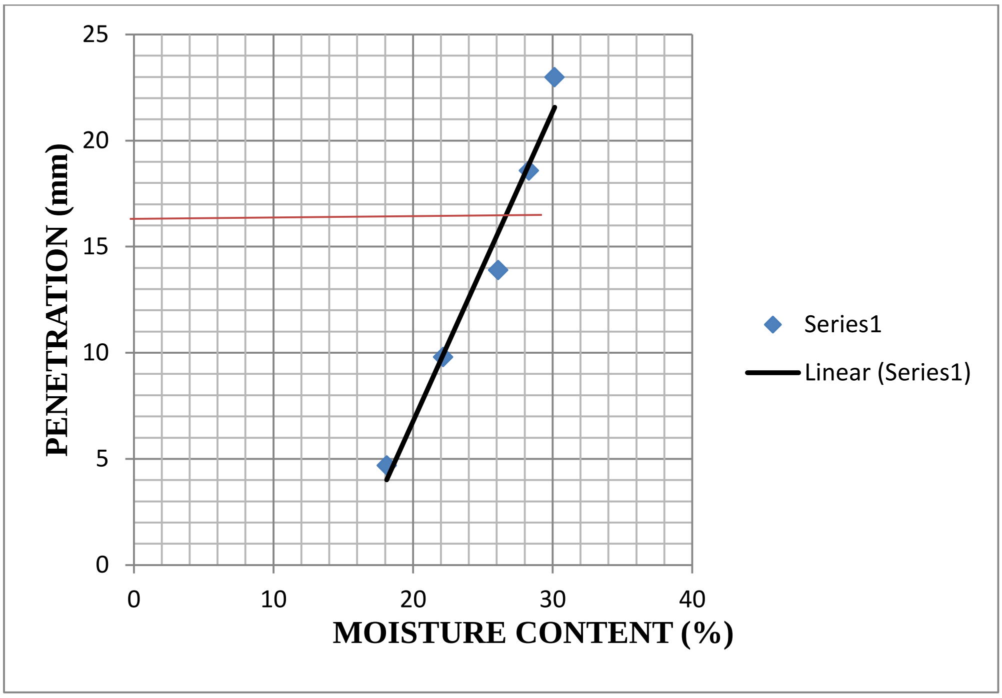

Figure 4: Liquid Limit at 3.0m

Table 5and 6 below shows Grain size analysis.

Table 5. Grain size analysis at 2.0m depth

Sieve size (mm)	Mass Retained (g)	Percentage Retained (%)	Percentage Passing (%)
5.000	0	0.00	100.00
3.350	0	0.00	100.00
2.000	0	0.00	100.00
1.180	0.5	0.17	99.83
0.850	0.3	0.10	99.73
0.600	0	0.00	99.73
0.425	0.2	0.07	99.67
0.300	0	0.00	99.67
0.150	0.7	0.23	99.43
0.075	4.4	1.47	97.97
0.030	Hydrometer Analysis		92.32
0.0021			87.12
0.016			81.65
0.011			75.13
0.008			70.27
0.007			66.16
0.005			60.11

Table 6. Grain size Analysis at 3.0m depth

Sieve size (mm)	Mass Retained (g)	Percentage Retained (%)	Percentage Passing (%)
5.000	0	0.00	100.00
3.350	0	0.00	100.00
2.000	0	0.00	100.00
1.180	0.2	0.7	99.93

0.850	0.3	0.10	99.83
0.600	0.2	0.07	00.77
0.425	0.1	0.03	99.73
0.300	0.1	0.03	99.70
0.150	0.5	0.17	99.53
0.075	4.3	1.43	98.10
0.030	Hydrometer Analysis		94.72
0.021			89.45
0.016			81.58
0.011			76.10
0.008			71.26
0.007			67.18
0.005			61.42

Figure 5 below shows the sieve analysis graph of percentage passing against particle size at 1.0m, 2.0m and 3.0m depth.

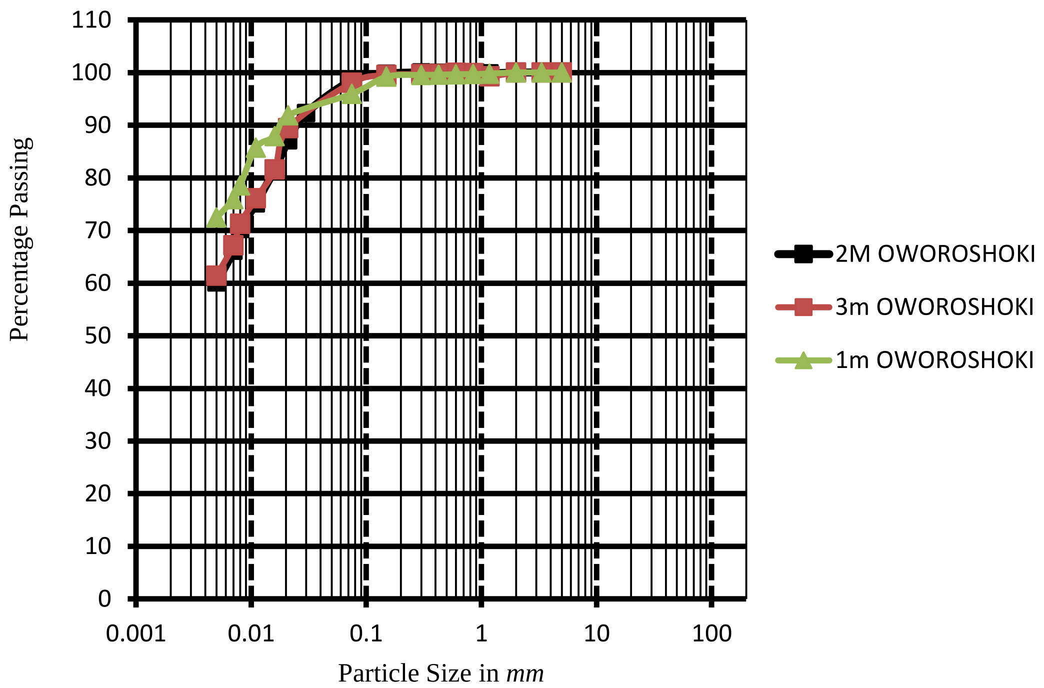

Figure 5: Sieve Analysis Graph

Specific Gravity

The specific gravity of soil sample at varying depths is presented in Table 7 below.

Table 7. Specific Gravity

Depth (m)	Specific gravity (Gs)
1.0	2.61
2.0	2.55
3.0	2.60

Figure 6 below shows the specific gravity graph of specific gravity against depth at 1.0m, 2.0m and 3.0m depth.

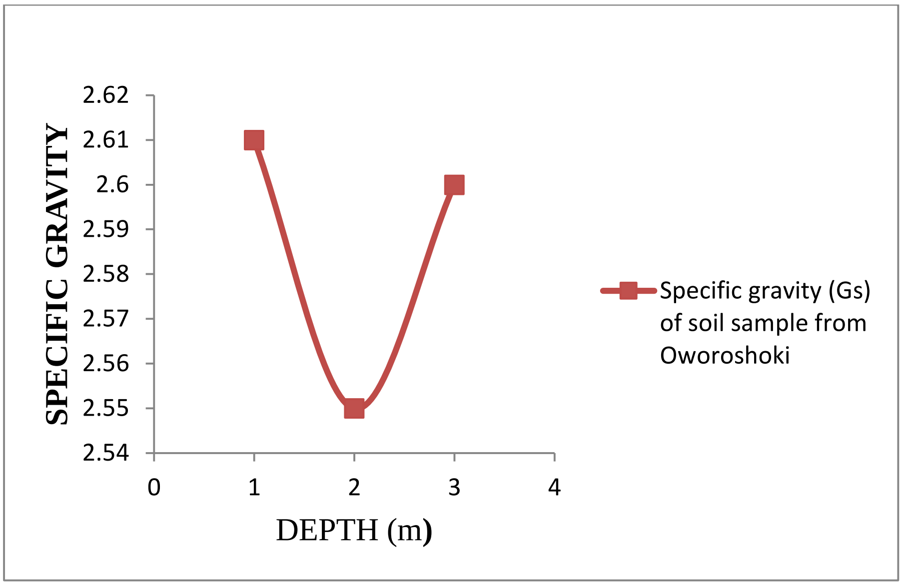

Figure 6: Specific Gravity Graph

Unit Weight

The Unit Weight of soil sample at varying depths (1.0m, 2.0m and 3.0m) is presented in Table 8 below.

Table 8. Unit Weight

Depth	1	2	3
Weight of mould (g) W1			
W2			
Weight of soil sample (g) W3 =(W2-W1)			
Volume (cm^3)			
Density p W3/volume (g/cm)			
Unit weight px9.81 (KN/m^3)	17.5	18.1	18.9

Figure7 below shows a graph of unit weight against depth at 1.0m, 2.0m and 3.0m.

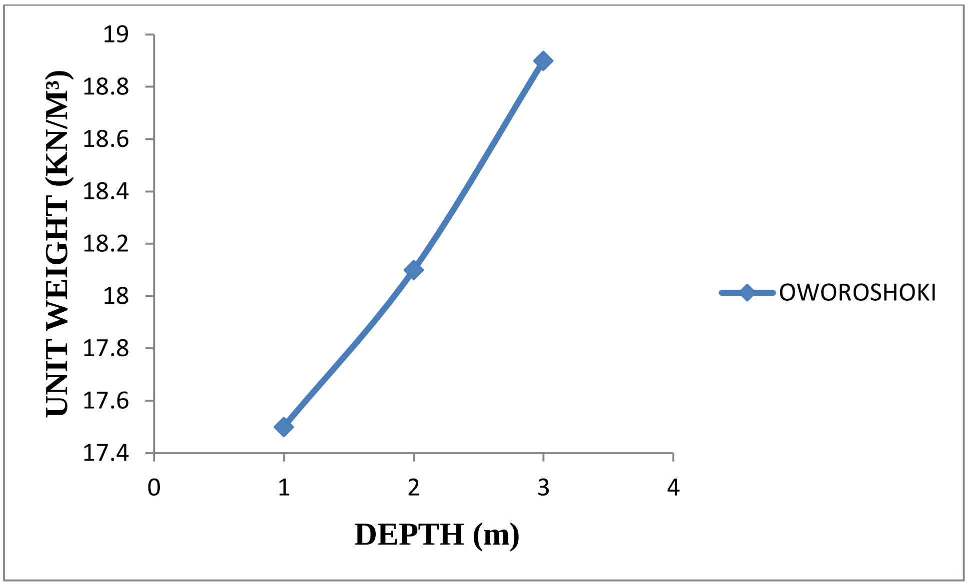

Figure 7: Unit Weight Graph

Characterization

The Characterization of soil sample at varying depths is presented in Table 9 below.

Table 9. Characterization of soil sample at 1.0m, 2.0m and 3.0m

Characteristics	1.0m	2.0m	3.0m
Natural Moisture content (%)	23.5	24.5	25.3
Specific Gravity	2.61	2.55	2.60
Unit Weight (KN/m^3)	17.5	18.1	18.9
% passing sieve 200(0.075mm)	95.97	97.97	98.10
Liquid Limit %	28.68	26.64	29.10
Plastic Limit %	-	-	-
Plastic Index %	-	-	-
AASHTO Classification	A-3	A-3	A-3

DISCUSSION OF RESULTS

The natural moisture content of Olworoshoki is given as 23.5%, 24.5% and 25.3%. It has the highest retention capacity of water of 25.3% at 3.0m depth. It has liquid limit of 28.68%, 26.64% and 29.10%. Oworoshoki is non-plastic (PI = 0) for the three depths. Oworoshoki soil sample percentage passing through BS #200 (0.075mm) is 95.97 %, 97.97%, 98.10%. This shows that the soil sample contain much silt, the samples are non-plastic (NP) for all depths (1m, 2m and 3m) and are classified as A-3. It has high percentage passing through BS #200 (0.075mm) with a value of 98.10%.The specific gravity (Gs) of Oworoshoki is 2.61, 2.55 and 2.60. It has the unit weight of 17.5 KN/m^3, 18.1 KN/m^{3}and 18.9KN/m^3. Hydrometer test is only conducted when an appreciable quantity of soil sample passes through BS #200 (0.075mm). Base on this fact Oworoshoki soil samples were tested for hydrometer.

CONCLUSION

The result of soil samples has revealed the characteristics of the soil within the study area. It has shown that the area is dominated by silt soil because the percentage passing BS #200 (0.075mm) at depth 1.0m, 2.0m and 3.0m is 95.97%, 97.97% and 98.10% respectively which is greater than 35%. The soil sample at depth 1.0m, 2.0m and 3.0m are nonplastic (NP) because the Plastic Index (PI=0) therefore the AASHTO classification of the soil is A – 3.Silt soil has low load bearing capacity compare to that of coarse soil which has high load bearing capacity. Since an appreciable quantity of soil has passed through BS #200 (0.075mm), hydrometer test becomes necessary and was conducted. It shows that the soil contain high amount of silt.

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