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Highway Geotechnical Properties of Some Lateritic Soils from the Sedimentary Terrain of the Lagos – Ibadan Highway

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ABSTRACT

Samples of the foundation soil of an unstable section of the Lagos – Ibadan highway around Sagamu were investigated with a view to evaluating them as highway sub grade materials and also establish any geotechnical basis, if any, for the observed pavement failure in the area.

Sixteen samples were collected from two locations in the study area. Parameters such as grain size distribution, consistency limits, Activity, Maximum dry density, (MDD), Optimum moisture content (OMC), unconfined compressive strength, California bearing ratio (CBR) and Permeability were determined. These parameters obtained for the two locations were compared with each other and emphasis was placed on the comparison of obtained results with some existing standard specifications for highway sub grade soils.

The results of the investigations showed that the sub grade soils from both locations have the same degree of laterization and they are poorly graded being rich in fines and deficient in intermediate particles. Casagrande chart classifies soils from both locations as inorganic intermediate plastic soils, while American Association of State Highway and Transportation Officials (AASHTO) classification system groups them as fair to poor sub grade materials. Although, the investigation showed that the predominant clay mineral in both locations is kaolinite, they were found to have plasticity, liquid limits and linear shrinkage values higher than the recommended standard values. It was also discovered that while soils from locations showed good compaction parameters, they exhibit high water retention capacities and poor drainage characteristics. The CBR (California bearing ratio) of soils from both locations are generally lower than recommended values and were reduced greatly on after soaking. The foundation soils from both locations therefore fall short of recommended standards for good highway sub grade materials.

Key words; Consistency limits, Grain size distribution, Lateritic soils, Sub grade, Permeability

INTRODUCTION

One of the resounding reasons why Nigeria has not been able to attain her potential is the poor state of her road infrastructure. [1]. The Lagos – Ibadan highway is a very important highway as far as the economy of Nigeria is concerned. For many years has serve as a useful link between Lagos and most part of the Northern Nigeria. It is located approximately on longitude 4^{o}22′E and 7^{o}20′N. Failure spots characterized by remarkable waviness are common features of the major road especially the Ibadan - bound carriage way.

This does not only impede free flow of traffic along the highway, but has also been responsible for fatal accidents. Although, several factors might have contributed to this failure, it is pertinent to note that most materials on which most Nigerian roads are built are not in harmony with highway sub-grade specifications. [2] studied sub grade soils from Ado – Ekiti, Southwestern Nigerian, and reported that the highway failure in the area can attributed to excessive fine fraction content of the sub grade soils.[3] attributed pavement failure to in some parts of southeastern Nigeria to changes in pavement condition due to interaction of local raod aggregate with water causing swelling, stripping and potholing.[4] inferred that the degree of stability of the flexible road pavement is increased with both the amount of Kaolinte present in the sub grade soils and their California Bearing Ratio and Unconfined Compressive Strength. [5] identified that most of road failures in the tropics can be attributed to geotechnical factors.

This paper intends to investigate the geotechnical properties of foundation soils in two unstable locations with a view to determine the geotechnical basis if there is any for the observed failure cases on this major highway and hence, and make recommendations that can help to make the road aesthetically pleasing, socially acceptable and environmentally compatible. The recommendations made in this paper can also help to minimize further degradation of the highways in other geological and geographical terrain.

The study area falls within the Sedimentary rock portion of the highway around Sagamu. Samples were taken from two different locations which makes about 2.4Km stretch of the unstable section along the Lagos carriage way. Although, the Ibadan bound lane is more unstable due to heavier traffic. The first location is situated opposite an uncompleted filling station about 56Km to Lagos from Ibadan. The co-ordinates are N60^{0}51′29.3″ and E003^{0}32′28.4″ at an accuracy of 8m.The elevation of the area is about 43m above sea level. The second Location is situated about 2.4Km from location one. It is opposite Conoil filling station, Kilometer 53.6 to Lagos. The co-ordinates are E003^{0}32′28.4″ and N06^{0} 52′06.8″ at an accuracy of 8m. The elevation is 77m.These two locations are directly accessible the highway (Lagos carriageway), because they are located along the road side and this exposures can be described as road cut.

GEOLOGY AND PHYSICAL SETTING OF THE AREA

The study area falls within the Benin (Dahomey) basin which forms one of a series of west African Atlantic Margin basins that are initiated during the period of rifting in the late Jurasic to early Cretaceous. [6] and [7] also reported that the basin is made up of Tertiary to Recent sediments and Cretaceous sediments. The area is underlain by Ilaro formation coastal recent sediments overlie the formation. It is however observed that the basement complex are found within the sedimentary basins but deeply buried by the overlying Cretaceous and younger sediments about 2.5Km thick. The area has a tropical climate characterized by two seasons; the wet season starts mid-March and end October with an average annual rain fall of 180mm to 370mm while the dry season starts around November and ends in March with an average maximum temperature of about 31^{0}C. The relative humidity is usually above 56% as a result of the moisture laden, southeast wind blowing towards the Guinea coast. However, this could also be as a result of the proximity to the Atlantic Ocean.

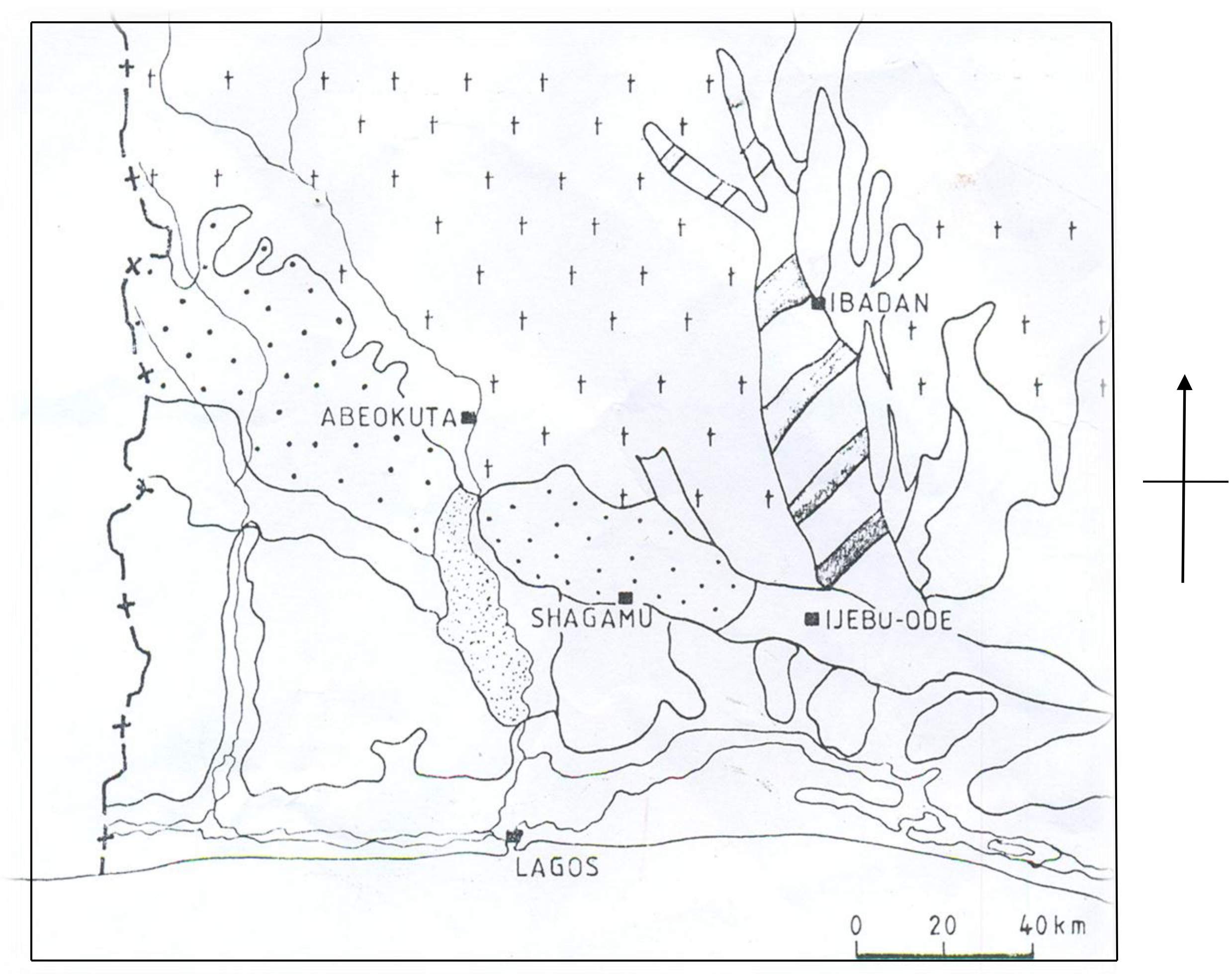

Fig.1. Geological Map of study area (Modified after [8])

METHODS

A total of sixteen samples were taken; eight bulk samples and eight smaller samples. A set of four bulk samples and four smaller samples were taken from a location, another set of four bulk samples and four smaller samples were taken from a location another location about two and a half kilometers from locations one making a stretch of an unstable portion of the highway. Laboratory analyses were carried out on the collected samples and this involves grain size distribution analysis in conjunction with hydrometer analysis. The Specific Gravity of the soil samples were determined so as to infer the degree of lateralization [9].While the consistency limit tests were also carried out. At optimum moisture content, each sample was compacted both at West African and Modified AASHTO levels and the California Bearing Ratio Unconfined Compressive strength were evaluated [10].The permeability coefficients of the soil samples were also determined in order to evaluate the ease with which water will flow through them.

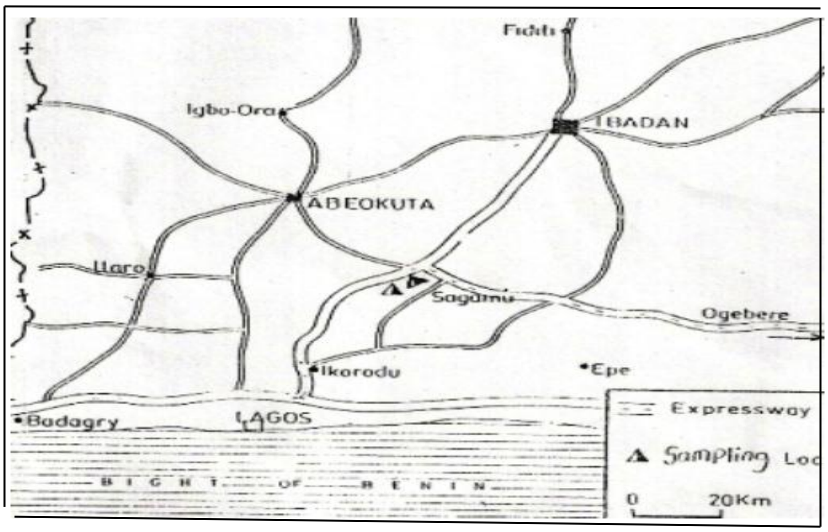

Fig.2. Location of the study area (Modified after [8])

RESULTS

The results of the geotechnical tests carried out on samples taken from two different locations below unstable section of the highway are presented in table 1, 2 3 and 4. The tests are grain size distribution, specific gravity of grains, consistency limits, compaction, California Bearing Ratio, unconfined compressive strength and permeability.

Sample number		GRAIN SIZE DISTRIBUTION					CONSISTENCY LIMITS			
		Gravel (%)	Sand (%)	Silt (%)	Clay content (%)	Amt of fines (%)	Liquid limit	Plastic limit	Plasticty index	Linear shrinkage
Location 1	A1	3.83	40.96	32.85	22.36	55.21	41.40	24.43	16.97	9
	B1	3.16	35.27	47.67	13.90	61.57	41.50	24.85	16.65	8
	C1	3.64	36.69	45.20	14.47	59.67	42.20	25.74	16.50	11
	D1	7.42	38.60	29.81	24.17	53.98	44.76	26.86	17.90	11

	E1	4.65	39.85	33.00	22.50	55.50	41.60	24.50	17.09	8
	F1	3.75	38.33	53.25	4.67	57.92	40.50	24.60	15.90	8
	G1	3.55	35.67	53.02	7.76	60.78	41.08	24.74	16.34	6
	H1	8.75	39.00	45.64	6.61	52.25	43.00	26.28	16.72	7
Location 2	J2	1.56	26.86	54.35	17.23	71.58	42.20	25.30	19.90	11
	K2	1.57	28.70	52.86	16.87	69.73	48.98	27.57	21.41	12
	L2	1.63	29.88	48.46	20.03	68.49	47.00	26.52	20.68	12
	M2	1.24	25.57	56.67	16.41	73.19	48.80	29.27	19.06	19
	Q2	2.08	31.23	59.67	7.02	66.69	45.20	25.30	19.90	12
	R2	1.81	29.92	62.67	5.55	68.27	48.00	26.30	21.70	13
	X2	1.98	29.92	61.50	6.60	68.10	47.51	27.12	20.39	7
	T2	1.22	26.53	67.58	4.67	72.25	45.21	28.36	16.85	12

Table 1. Summary of the result of grain size distribution and consistency limit tests

Sample number		Modified AASHTO				West African			
		Unsoaked CBR	Soaked CBR	% Strength reduction	% of water absorbed	Unsoaked CBR	Soaked CBR	% Strength reduction	% of water absorbed
Location 1	A1	14.50 19.26	2.00 2.49	86.20 87.07	 24.97	12.67	2.27	82.24	38.19
	B1	11.33 22.43	2.70 2.49	76.17 78.78	24.97	10.20 15.63	2.27 3.40	77.25 78.25	35.82
	C1	14.95 25.60	3.97 6.57	73.44 74.34	21.78	12.99 20.39	2.27 4.08	82.52 77.75	40.33
	D1	12.24 19.03	3.85 5.00	68.55 73.73	28.00	11.33 16.77	2.95 3.74	73.96 77.70	32.78
Location 2	E1	10.0 15.41	1.59 2.50	84.10 83.78	26.15	2.90 7.48	1.25 1.81	56.90 75.80	17.72
	F1	10.20 15.86	3.85 5.44	62.25 65.70	31.73	4.53 8.61	3.40 4.31	24.94 49.94	19.64
	G1	9.52 16.52	3.29 3.51	65.44 78.78	16.07	3.06 4.53	2.27 2.27	25.58 49.89	36.6
	H1	4.31 9.06	3.29 5.21	23.67 42.49	32.83	3.51 7.70	2.40 3.40	41.88 55.84	9.3

Table2. Result of California Bearing Ratio

Specific Gravity

[10]suggested the use of specific gravity in investigating the maturity of lateritic soils. He stated the specific gravity of soils is an indication of its degree of laterization. The higher the specific gravity and the degree of laterization of a soil, the stronger the soil. Location one and location two exhibit the same degree of laterization, hence it can be inferred that they both have similar strength.

Grain Size Distribution Analysis

The studied soils from both locations one and two are poorly graded being deficient in intermediate size particles. The proportion of fines in location two is about 70% on the average, while he amount of fines in location one is lower averaging 50%.

The quantity of fines in these two locations is higher than the required 15% maximum value on this basis. They can be said to be poor sub-grade materials because the lower, the quantity of fines in a soil, the better its engineering characteristics. The soils from both locations fall under group A7 of AASHTO classification and they are both rated as fair to poor sub grade materials under the same specification.

Sample number		Moisture dry density relationship				Unconfined compression test			
		West African		Modified AASHTO		West African (KN/KM^2)		Modified AASHTO (KN/KM^2)	
		MDD (kg/m^2)	OMC (%)	MDD(kg/m^2)	OMC (%)	Uncured strength	Cured strength	Uncured strength	Cured strength
Location 1	A1	1880.00	19.30	1710.00	22.00	63.13	1193.82	96.53	1216.78
	B1	1915.00	18.20	1730.00	21.25	83.66	1216.93	75.13	1366.91
	C1	1925.00	18.00	1710.00	20.80	97.93	1358.30	56.80	1386.54
	D1	1900.00	19.25	1750.05	21.19	50.90	1233.84	66.6	1274.89
Location 2	E1	1670.50	23.20	1845.00	20.15	44.67	1124.34	44.677	1124.34
	F1	1630.00	23.41	1825.00	19.45	43.57	1030.14	43.57	1030.14
	G1	1912.00	19.07	1740.00	12.23	40.22	1164.06	40.22	1164.06
	H1	1710.00	22.60	1880.26	19.35	103.60	1166.53	103.6	1166.53

Table 3. Result of compaction and unconfined compressive tests

Consistency Limit Tests

The values for the liquid limit for location one range between 40.55% and 44.76%, the mean value being 42.01. For location two, the range of liquid limit values is between 42.20% and 48.98%, the average being 46.61%. These values when compared with [11], is higher than the 30% maximum liquid limit recommended for highway sub-base materials. These imply that the studied soils from the two locations are poor sub-base materials, because higher values than the specified value are an indication that the water retention capacity of these materials is very high.

The plastic limit of location one samples range between 24.6%, 26.86%, the mean value being 25.25%. For location two, the plastic limit range between 25.3% and 29.74%. The mean value is 27.03%. These plasticity values are generally higher than 25% the maximum recommended for sub grade tropical soils [12] The Casagrande chart indicates medium or average plasticity. The plasticity index for location one has a mean value of 16.76 while that of location two averages 17.74. The Federal Ministry of works gives a specification of 12 as the upper limit for plasticity index for good sub-base materials. Obviously, these two locations have plasticity index that is higher than 12. It can be inferred from activity values these the predominant clay mineral in both location is Kaolinite. This implies that soils from both locations are expected to have better geotechnical characteristics and exhibit better drainage properties than observed. The linear Shrinkage for location ones ranges between 6.1 and 11%, the mean value being 8.51%. For location two, the range is between 19% and 11% the mean value been 12.25%. Based on the Federal Ministry of work specification and [4]; the maximum value for highway sub-base materials is 8%, therefore studied soils can be rated as poor. This is because, the lower the linear Shrinkage of a soil the better it is as a sub-base materials.

Moisture Density Relationship

The optimum moisture content (OMC) of soils compacted at West African level for location one ranges between 18.0% and 19.30%, the average being 18.69%, while that of location two range between 19.35% and 22.23%, the average being 22.07%. The maximum dry density (MDD) under the same level of compaction for location one range between 1880 kg/m^3 – 1925 kg/m^3, the average being 19.05kg/m^3. For modified AASHTO level of compaction the Optimum moisture content for location one range between 20.80% and 21.32, the mean 21.32%. While that of location two ranges between 19.07% and 23.41%, the mean being 20.30%. At the same level of compaction, the maximum dry density (MDD) for location one averages 1735.00kg/m^3 while that of location two averages 1822.57kg/m^3. Both locations have good compaction parameters.

After compacting the soil samples at both West African level and modified AASHTO level of compaction, they were subjected to sieve analysis in order to study the impact of compaction on the grain size distribution of the soil samples with respect to increase or decrease in the quantity of fines as a result of compaction. It is noticed that the quantity ofines in the compacted soils do not change appreciably indicating that these samples were not over compacted.

California Bearing Ratio (CBR)

The CBR test often gives a good estimate of the bearing capacity of highway sub grade materials [10]. The average value for the unsoaked CBR under the West African level of compaction are 13.04 and 5.29 location one and two respectively. The soaked

CBR have average values of 2.84 and 2.55 for locations one and two respectively. The strength reduction is 66.62% and 47.63% for location one and two respectively. For the samples compacted at the modified AASHTO level of compaction, the soaked CBR values averages 14.62 and 11.36 for locations one and two respectively. The strength reduction is 77.29 and 63.28 respectively. These results show that location one experienced a higher strength reduction on account of soaking than location two. It is also apparent that location one has a higher unsoaked CBR value compared with location two. However none of these soils from both locations meet the earlier on specified values, none could be adjudged fit as sub-base or base-course materials. The result also shows that CBR of the soils reduce greatly as a result of soaking, and the amount of water absorbed is more than 20%. This further stresses the fact that these soils have high water retention capacity and that adequate drainage is required in order to prevent ingress of water below the pavement, which could result in a significant loss of strength of the sub grade soils and hence failure of the overlying pavement.

Unconfined Compressive Strength (UCS)

It is observed that the cured and uncured unconfined compressive strength of samples from location one is a bit lower than that of location two for both levels of compaction. The uncured strength for location one averages 73.91KN/m^2 and 78.77KN/m^{2-} for West African level of compaction and modified AASHTO level of compaction respectively. While the cured strength averages 1250.60KN/m^2 and 1200.8KN/m^2 for West African level of compaction and modified AASHTO level of compaction respectively. For location two, the uncured strength averages 58.04KN/m^2 and 80.2KN/m^2 for samples compacted at West African and Modified AASHTO respectively. The cured strength averages 1250.60KN/m^2 and 1135.52KN/m^2 for samples compacted at West African and Modified AASHTO respectively.

From these result, it also apparent that the soil samples from both locations are very sensitive to curing. That is there is great increase in strength as a result of curing. This implies that these soils are very rich in clay size particles. However for both locations, it is apparent that the cured strength is lower than the minimum acceptable value of 103KN/m^2 [13], while the cured strength is generally higher than 1034 KN/m^2 recommended by the Central Road Research Institute of India reported by [14].

Permeability

The average permeability coefficient value for location one is $4.3x10^{-5}$mm/s while the average permeability coefficient value for location two is $3.6x10^{-5}$ mm/s. These two values fall within the margin of soils with poor drainage property. That indicates the soils from the two locations have poor drainage properties and water does not flow with ease through them.

CONCLUSION

Geotechnical investigation of soils from two locations in the unstable section of the Lagos –Ibadan highway shows that soil from both locations have a low level of laterization they are both poorly graded and rich in fines. The amount of fines in the two locations is much higher than the recommended 15% maximum value. They can be said to be poor sub-grade materials because the lower, the quantity of fines in a soil, the better its engineering characteristics. The soils from both locations fall under group A7 of AASHTO classification and they are both rated as fair to poor sub grade materials under the same specification.

The liquid limit plastic limit of both locations are generally higher than the recommended for sub grade tropical soils, this is closely linked to their high water retention capacities and poor drainage properties while the high plasticity might be the cause of the observed waviness in the area. Although location one shows a greater strength reduction as a result of soaking than location two none of the two locations met up with the specifications for highway sub-grade materials. Adequate drainage should therefore be provided in the area in order to prevent ingress of water below the pavement which could result in significant loss of strength of the sub grade soils and hence failure of the overlying pavement.

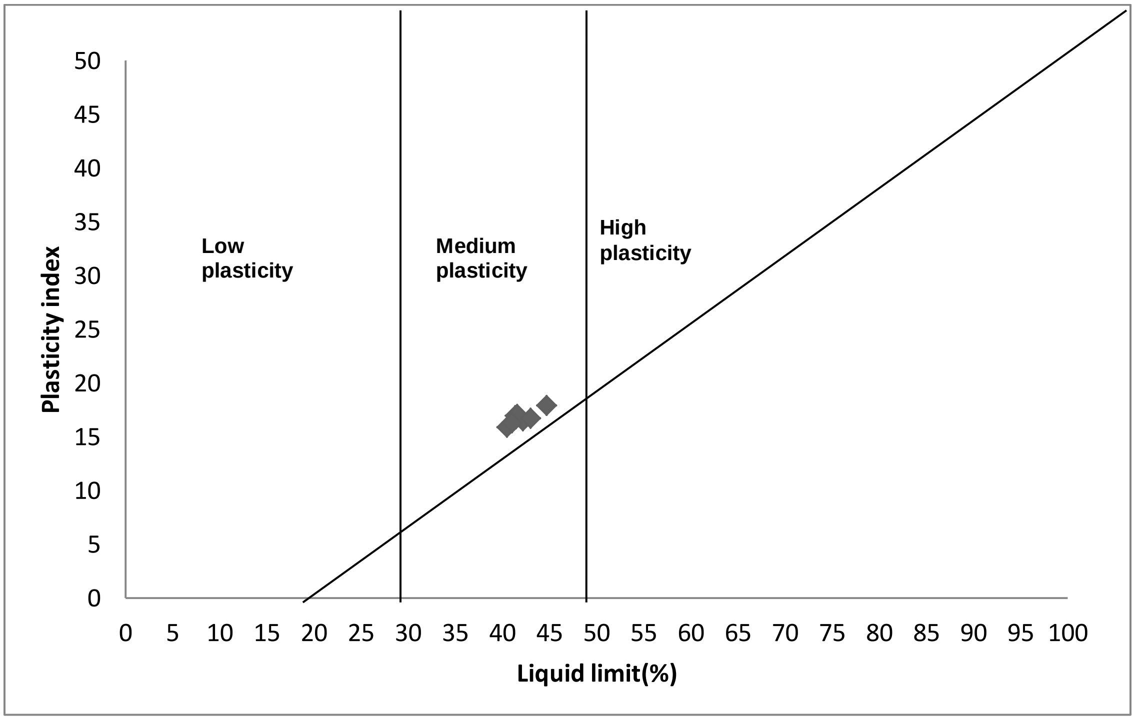

Fig3. Casagrande chart classification of the studied soils, location one

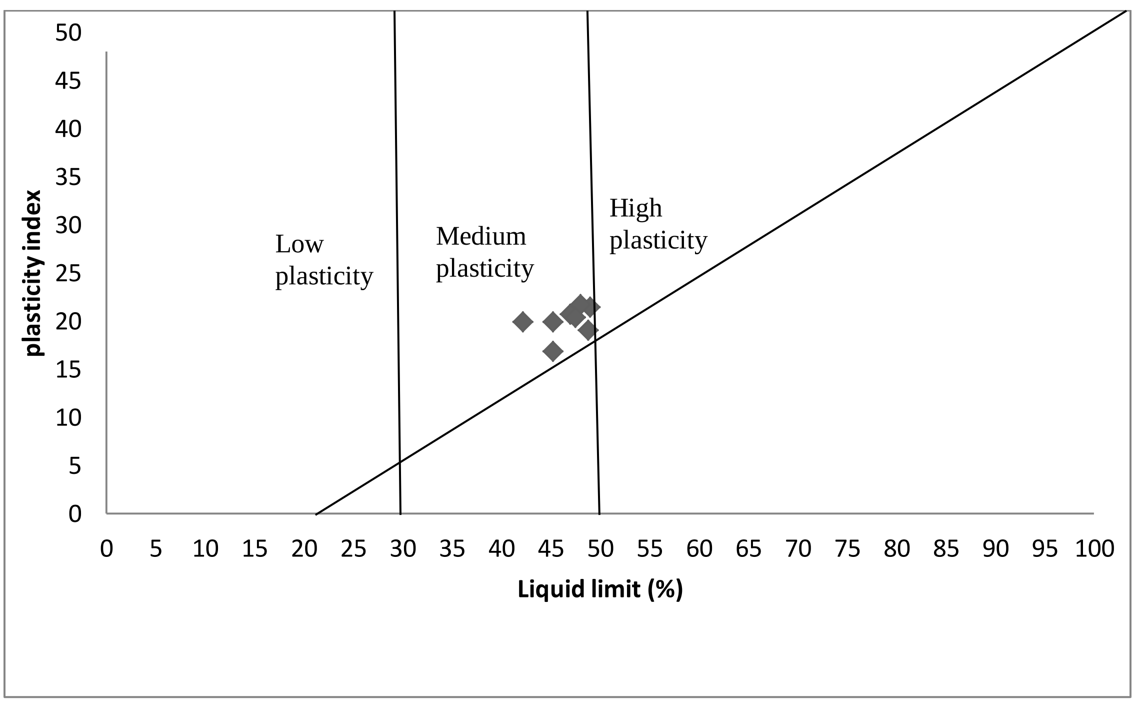

Fig.4. Casagrande chart classification of the studied soils, location two

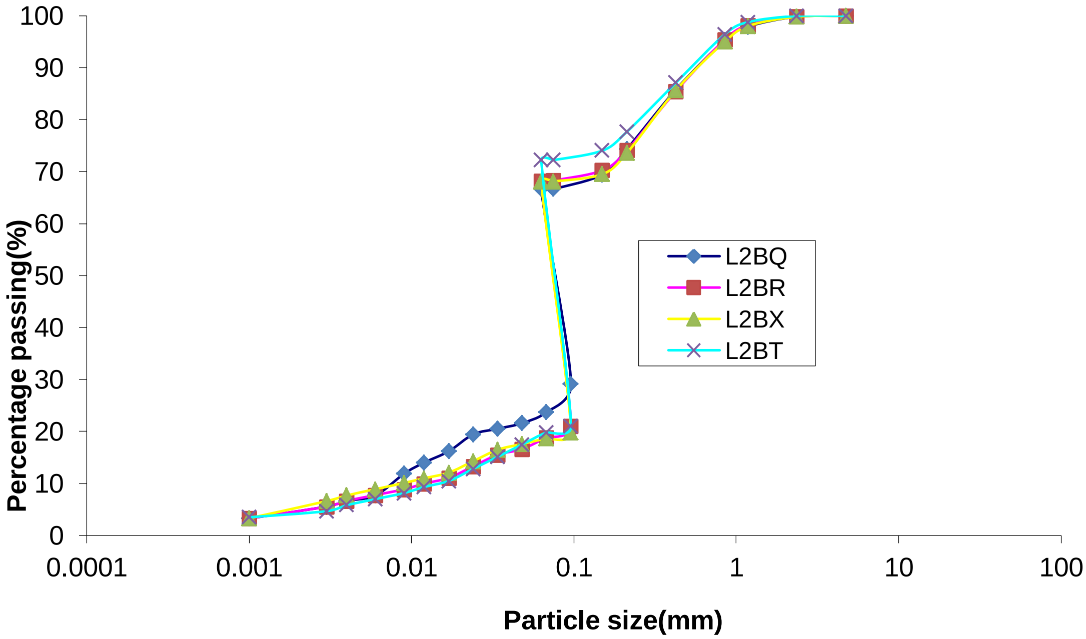

Fig.5 Grain size distribution charts for location two

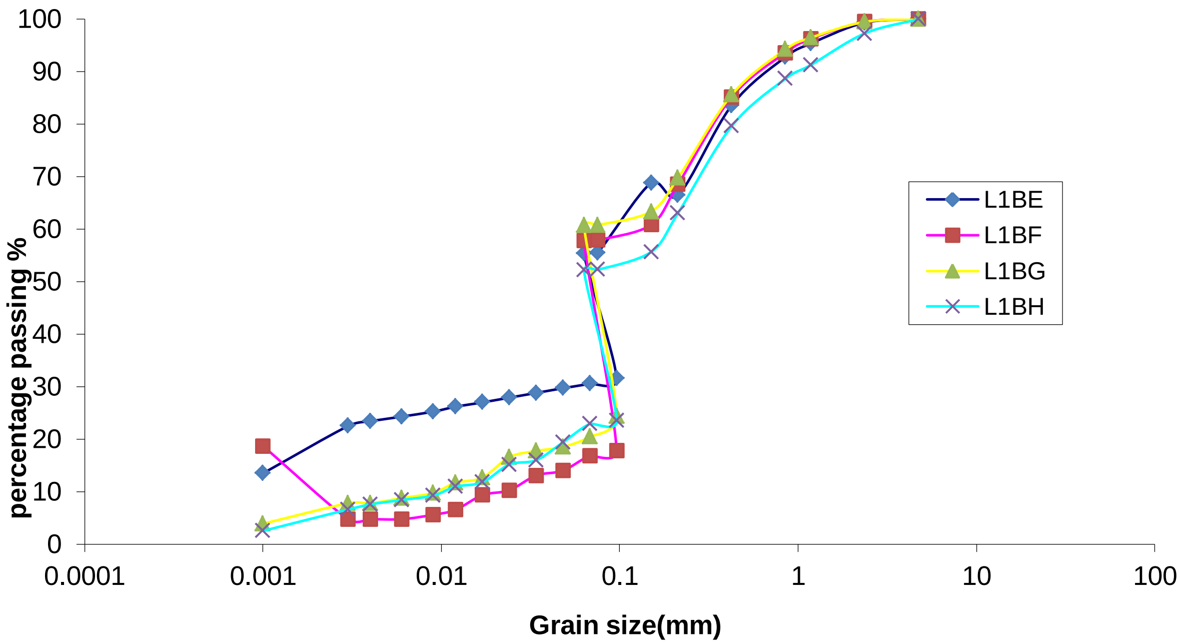

Fig.6. Grain size distribution chart for location one

REFERNCES

[1]Federal Road Management for Sub-Saharan African Nations: A Nigerian Case Study. thesis, university of Waterloo, Ontario, Canada.

[2] Effect of Soil Properties on Pavement Failures along the F209

Highway at Ado - Ekiti, South-western Nigeria. Construction and Building Materials, Vol. 14, pp. 311-315.

[3] Impact of hydrology on the Port-Harcourt – Patani-Warri Road. Environmental Geology, Vol. 40, pp. 153-162.

[4] Highway Geotechnical Properties of Lateritised Residual Soils in the Ajebo-Ishara Geological Transihon Zone of Southwestern Nigeria. Unpublished Ph.D Thesis, Obafemi Awolowo University, Ile-Ife, Nigeria. Vol. 1. pp. 115-118.

[5] Laterite Soil Engineering, Elsevier, Amsterdam, 554pp.

[6] Tectonic evolution and Cretaceous Stratigraphy of the Dahomey basin. Journal of Mining and Geology. 18; pp130 - 137

[7] Geology and mineral Resources of Nigeria, Lecture Notes in Earth Sciences.120,D010.10007/978

[8] Geotechnical properties of lateritic soils developed over quartzschist in Ishara Area Southwestern Nigeria.J. Mining Geology., 38;65 -69.

[9] "The correlation between Engineering and Pedological Classification System inWestern Nigeria and its Implications" Reg. *Conf. Africa Soil Mech. Found Eng.* 3rd Ed. Salisburg, Rhodesia Vol. Adegoke, O.S., (1969). Eocene Stratigraphy of Southern Nigeria, Bur. Rech. Geol. Min. Mem. N.O. 69, pp. 23-48.

[10] "Geotechnical Evaluation of Residual Gravels in Pavement construction" *Eng. Geol*. 15, pp. 173 – 192, 1980.

[11] Specification for Roads and Bridges. 2, 137 – 275pp

[12] Simeon, A.B., Geisecke, J. and Bidlo, G., (1973), Use of Lateritic soils for Road Construction in North Dahomey. *Engineering Geology*. 7: pp 197 – 218.

[13] Laboratory test on the influence of cement, lime and bitumen or soils; Journal of Transportation Division, American society of Civil Engineers.

[14] Engineering Characteristics (general report). *Proceedings of the Specialty Section on Engineering Properties of Lateritic Soils*. 7th International Conference on Soil Mechanics and Foundation Engineering, Mexico, 1, pp 17 – 128.

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