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Correlation of unified and AASHTO soil classification systems for soils classification

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Abstract

Seven laterite samples derived from Akure, Ondo, Owo, Oshogbo, Ilesha, Ado-Ekiti and Ijan Ekiti in South-west Nigeria were classified using Unified an AASHTO soil classification systems. Unified soil classification was carried out in accordance with ASTM D2487-93 while AASHTO soil classification was carried out in accordance with AASHTO M145-88. The results of the two soil classification systems were correlated. Base on Unified soil classification, Loc.1 to Loc.3 are SM (silty sands), Loc.4 is CH (clayey soil of high plasticity), Loc.5 is CI (clay soil of medium plasticity), while Loc.6 and Loc.7 are SC (clayey sands). Base on AASHTO soil classification, Loc.1 is A-4(0)(silty soil), Loc.2 is A-6(3) (clayey soil), Loc.3 is A-1-b(3) (gravel and sand), Loc.4 is A-7(20) (Clayey soil), Loc.5 is A-7(11) (Clayey soil), Loc.6 is A-7(8) (Clayey soil) and Loc.7 is A-7(6) (Clayey soil). Base on the results of two classification systems, only the results of Loc.2 soil results contradicts each other, hence it can be concluded that Unified AASHTO and soil classification systems give almost the same result and they can be used interchangeable.

Keywords: Unified, Soil Classification, Laterite, Weathering, plasticity, Temperature, Precambrian, In-Situ and undifferential.

1 Introduction

Laterite soils are usually the product of an in-situ (lateritic) weathering process of a basement rock, under tropical climate condition and since the Southwest Nigeria is a tropical region with mean annual rainfall in excess of 1200mm and average daily temperature greater than 25^0C, it has a climate ideal for the formation of laterite soils (Persons, 1970). Soil classification systems provide a language which communicates information in a brief manner without the necessary of lengthy description. Engineering soil classification can be done based on soil particle size and by soil plasticity. In geotechnical

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engineering field, numerous soil identification and classification system exist such as: Unified (ASTM D2487-93), America Association of State Highway and Transportation Officials (AASHTO M145-88) and U.S. Department of Agriculture (USDA) soil classification system. In this study, soil will be classified using Unified and AASHTO soil classification and the results will be compared to see if there is any relationship between the two soil classification systems.

2 Geology of the sample localities

The geology of Ondo State consists of two regions: region of sedimentary rocks in the south, and the region of Precambrian Basement Complex rocks in the north. The sedimentary rocks are mainly of the PostCretaceous sediments. The basement complex is mainly of the medium grained gneisses. These are strongly foliated rocks frequently occurring as outcrops.

Osun State is underlain by metamorphic rocks of the basement complex, which outcrop over many parts. Rocks of basement complex found here are schists associated with quartzite ridges found in Ilesha. Other parts of the state are underlain by undifferential metamorphic rocks.

Ekiti State is underlain by metamorphic rocks of the Precambrain basement complex. These basement complex rocks show great variations in grain size and in mineral composition. The rocks are quartz gneisses and schists consisting essentially of quartz with small amounts of white micaceous minerals.

Figure 1 presents the Geological Map of Nigeria showing the study areas and Figure 2 presents the sampling location map showing sample localities.

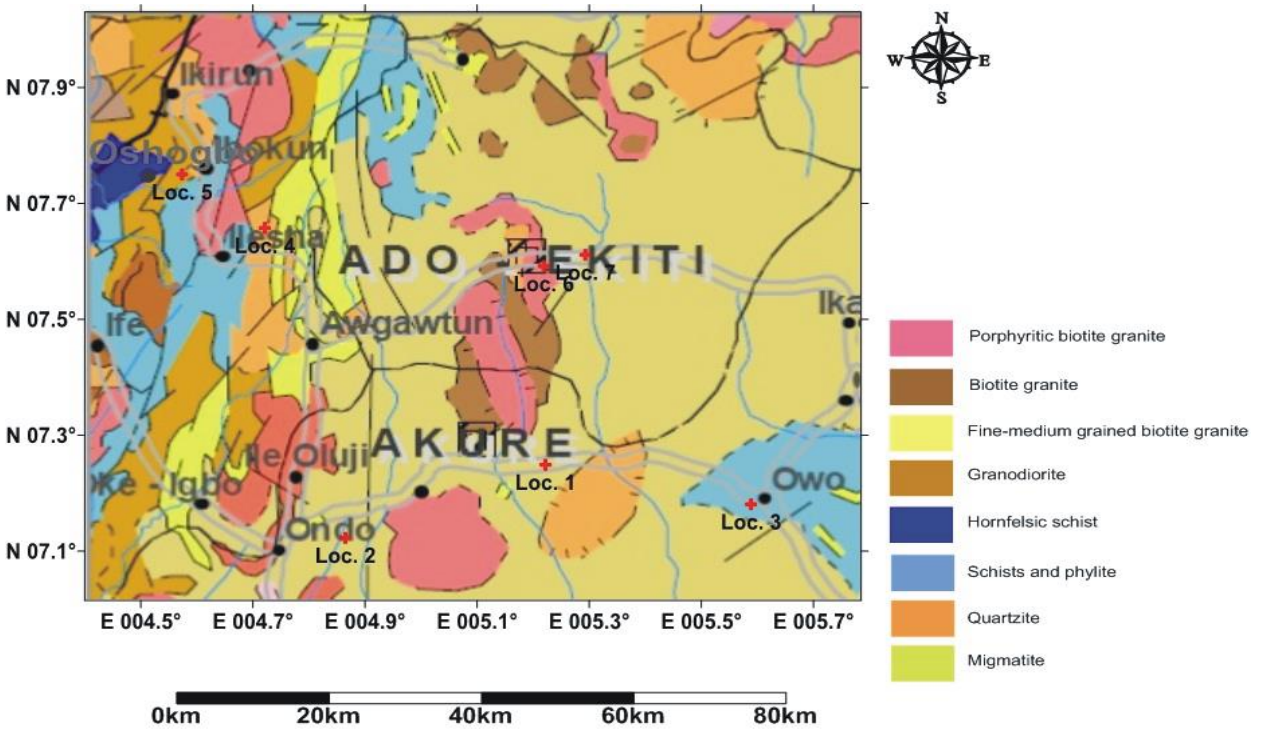

Fig 1: Geological Map of the Study Area

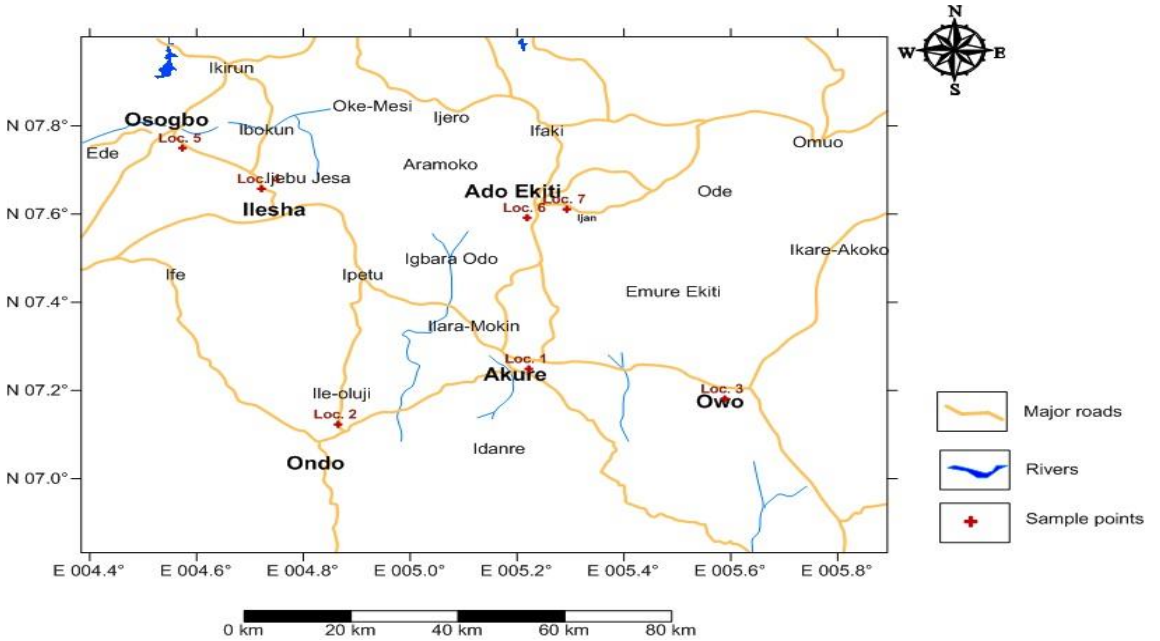

Fig. 2: Sampling Location Map Showing Samples Localities

3 Materials and methods

The study covers laterite deposits in Ondo, Osun and Ekiti States as representatives of Southwest Nigeria. The coordinates of locations in Ondo state: Akure ($07^0$14.94' N and $5^0$13.32' E); Ondo ($07^0$7.38' N and $04^0$51.9' E) and Owo ($07^0$10.85' N and $05^0$35.32' E); Osun state locations coordinate: Oshogbo ($07^0$44.99' N and $04^0$34.42' E) and Ilesha ($07^0$39.45' N and $04^0$43.29' E); and Ekiti state locations coordinate: Ado-Ekiti ($07^0$35.50 N and $05^0$13.13' E) and Ijan-Ekiti ($07^0$36.67 N and $05^0$17.58'E). The seven samples were obtained at depth between 1 and 3m and identified (Table 1). Samples were collected with the aid of digger, shovel, and clean polythene bags.

Table 1: Description of laterite samples

Sampling location	Sampling location code	Route (road)	Sample depth (m)	Sample colour
Behind Sunview hotel, Alagbaka Akure.	Loc.1	El-Shaddai road	2	Yellowish red
Igbo-Oja Ondo.	Loc.2	Ipetu-Ondo road.	3	Mottled yellowish red.
Adjacent Achiever University, Owo.	Loc.3	Owo-Ute-Uhen road	3	Yellowish.
Aladiye, Ilesha	Loc.4	Ilesha-Oshogbo road.	1	Reddish brown.
Opposite major garage, Oshogbo	Loc.5	Oshogbo-ilesha road.	2	Reddish
Opposite Yemtech Engineering, Ado-Ekiti	Loc.6	Ado-Ikere road.	2	Brownish red.
Odo-Ijan, Ijan-Ekiti	Loc.7	Ado-Ijan road.	1	Brownish red

3.1 Sample preparation and testing procedure

Samples and specimens were prepared in accordance with ASTM standards. The tests carried out on the samples are grain size analysis and atterberg limit tests.

3.1.1 Grain Size Analysis Test

The grain size distribution of each of the soil was determined using grain size analysis according to ASTM **(**2007a) D 422-63. The test was carried out using a set of sieves and hydrometer. The sieves were clean and assembled in ascending order of sieve number with No. 4 sieve at top and No. 200 sieve at bottom while the pan was placed below No. 200 sieve. The weight of the dry laterite sample was recorded and carefully poured into the top sieve while the cap was placed over it. The sieve stack was placed in the mechanical shaker and shake for 10 minutes. The stack was then removed from the shaker and the weight of each sieve with its retained soil was carefully weighed and recorded. The weight of the

bottom pan with its retained fine soil was weighed and recorded as well. Hydrometer test was conducted on the fine soils from bottom pan of the mechanical sieve set according to ASTM **(**2007a) D 422-63.

3.1.2 Atterberg Limit Test

This test was performed to determine the plastic, liquid limits, and Plasticity Index (PI) of the soils. The liquid (LL) is arbitrarily defined as the water content, in percent, at which a pat of soil in a standard cup which is cut by groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit (PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm diameter thread without crumbling. The laboratory procedure was carried out according to ASTM D 4318.

3.1.3 Unified Soil Classification

On the basis of the Unified Soil Classification System (USCS), soil with > 50 % of sample mass retained on the 0.074 mm sieve is term coarse-grained and if > 50 % of the coarse fraction is retained on 4.76 mm sieve, the soil is classified as gravel but if ≥ 50 % of the coarse fraction passes 4.76 mm sieve, such soil is sandy soil. Also the gravelly of sandy soil is classified further as well graded gravel/sand (GW or SW) or poorly graded gravel/sand (GP or SP) if percentage of the soil fines is < 5 %, but if the percentage of the soil fines is > 12 %, the soil plasticity index is plotted against its liquid limit and the soil is classified as gravel/sandy clayey (GC or SC) or gravel/sandy silty soil (GM or SM) depending on it position on the chart. On the other hand, if ≥ 50 % of the sample mass passes the 0.074 mm sieve, the soil is classified as fine-grained soil. The plasticity index of the soil fine-grained is then plotted against its liquid limit on plasticity chart to further distinguish the soil as silt or clay of low, medium, or high plasticity.

3.1.4 AASHTO Soil Classification

AASHTO soil Classification System classified soils in accordance with their performance as subgrade. To classify the soil, laboratory tests including sieve analysis, hydrometer analysis, and Atterberg limits which are used to determine the group of the soil. In the AASHTO system, the soil is classified into seven major groups: A-1 through A-7 as shown in Table 2.

Table 2**:** AASHTO Soil Classification (After AASHTO M 145-2)

General classification	Granular Materials (35 percent or less of total sample passing No. 200)				Silt-clay Materials (More than 35 % of total sample pass No. 200)	
Group classification	A-1	A-3	A-2		A-4 A-5	A-6 A-7
	A-1-a A-1-b		A-2-4 A-2-5	A-2-6 A-2-7		A-7-5 A-7-6
Sieve analysis percent passing No. 10 No. 40 No. 200	50max 30max 50max 15max 25max	51max 10 max	35max 35min	35max 35 max	36 min 36min	36 min 36min
Characteristics of fraction passing No. 40 Liquid limit Plasticity Index	6max	N.P.	40max 41min 10max 10 max	40max 41min 11min 11max	40max 41min 10max 10max	40max 41min 11min 11min
Usual types of significant constituent materials	Stone fragments-Gravel and sand	Fine sand	Silty or clayey and sand		Silty soils	Clayey soils
General rating as subgrade	Excellent to good		Fair to poor			

4 Results and discussions

4.1 Grain Size Analysis

The grading curves for the studied soils covers several log cycles of the semi-log paper, showing that they contain a variety of particle sizes, and are therefore well-graded. The results of grain size analysis test were presented in Tables 4.3 and 4.4 and Figures 4.1 to 4.7.

Table 3: Summary of Grain-Size Analysis Results (Loc.1 – Loc.7)

Sample	% Gravel size particles	% Sand size particles	% Fines	% Silt size particles	% Clay size particles
Loc.1	10.6	47.2	42.1	26.6	15.6
Loc.2	3.7	48	48.3	26.8	21.5
Loc.3	34.0	48.7	17.4	9.4	8.0
Loc.4	4.6	23.6	71.7	15.7	56.1
Loc.5	8.6	39.0	52.4	14.4	38.0
Loc.6	10.6	41.2	48.2	16.1	32.1
Loc.7	6.7	46.4	46.9	14.5	32.4

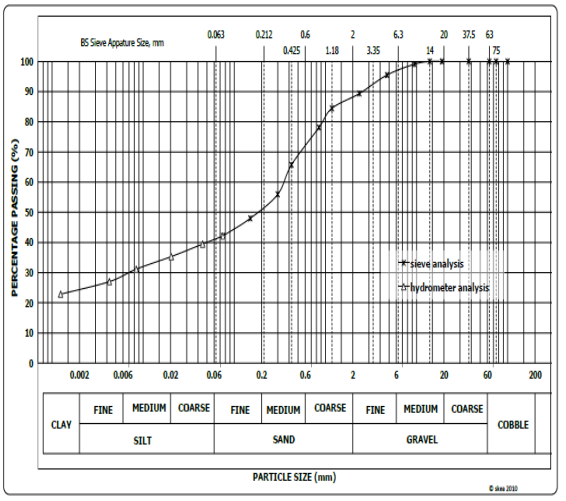

Fig. 3: Particle Size Distribution Curve (Loc.1)

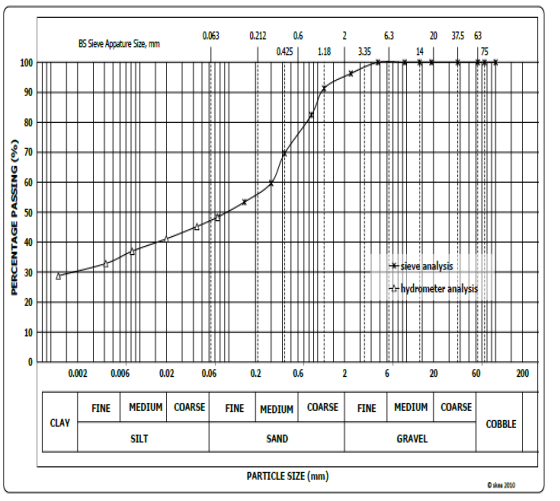

Fig. 4: Particle Size Distribution Curve (Loc.2)

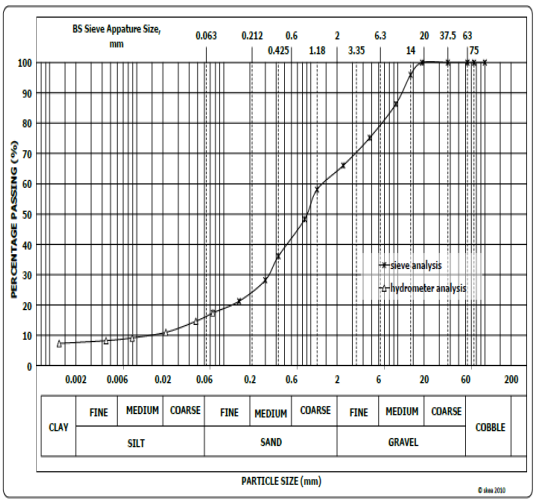

Fig. 5: Particle Size Distribution Curve (Loc.3)

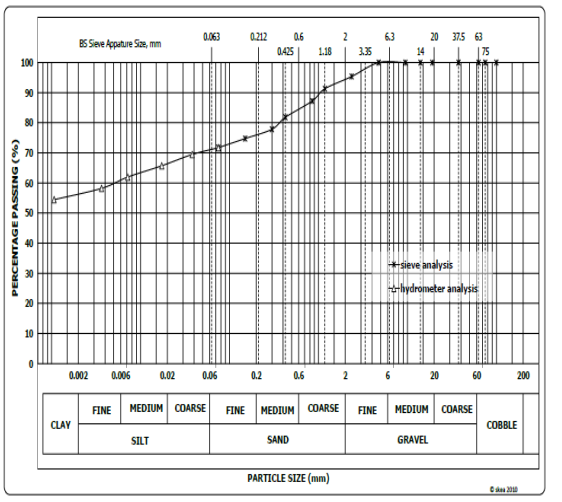

Fig. 6: Particle Size Distribution Curve (Loc.4)

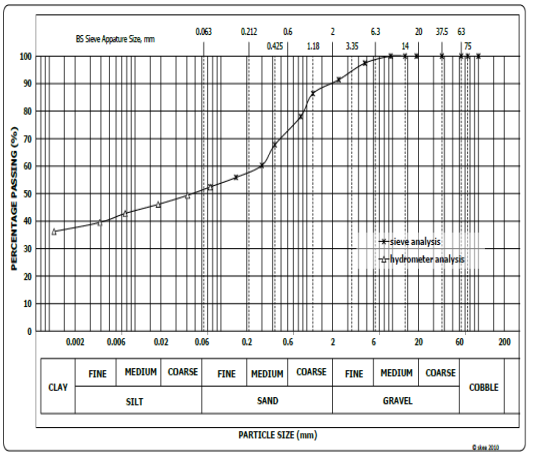

Fig. 7: Particle Size Distribution Curve (Loc.5)

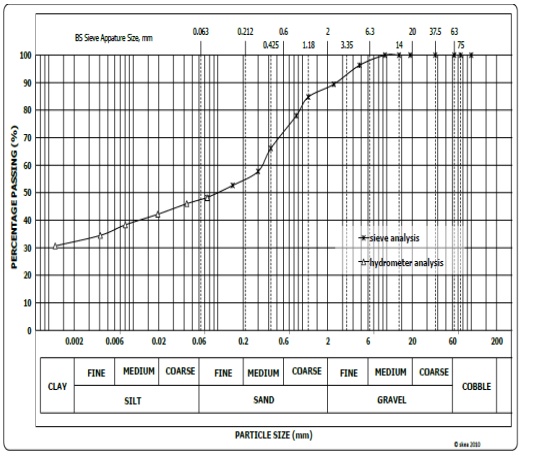

Fig. 8: Particle Size Distribution Curve (Loc.6)

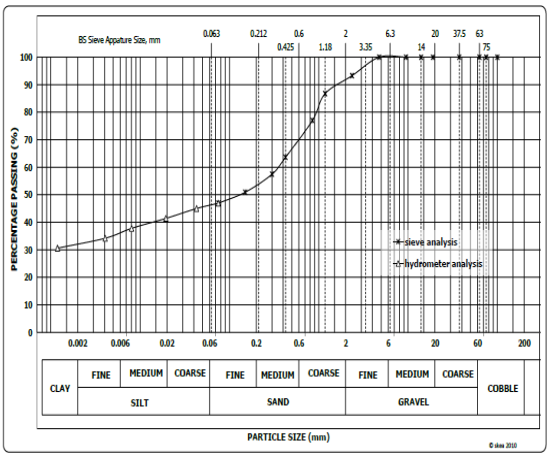

Fig. 9: Particle Size Distribution Curve (Loc.7)

4.2 Atterberg Limit Results

Table 4.5 presents the summary of the results of atterberg limit test conducted on the samples.

Table 4: Summary of Atterberg Limits Results (Loc.1 – Loc.7)

Sample	Liquid Limit (LL) (%)	Plastic Limit (PL) (%)	Plastic Index (PI)
Loc.1	34.3	27.4	6.95
Loc.2	39.6	27.4	12.20
Loc.3	28.1	24.2	3.95
Loc.4	65.8	20.3	45.53
Loc.5	48.3	19.5	28.85
Loc.6	44.0	19.2	24.80
Loc.7	41.8	22.2	19.60

4.3 Unified Soils Classification Results

The fine-grained soils plasticity index was plot against its liquid limit on the Casagrande's plasticity chart and the results are shown in Figure 4.73. The summary of the results of the classification of the laterites using Unified soils classification system is shown in Table 4.27.

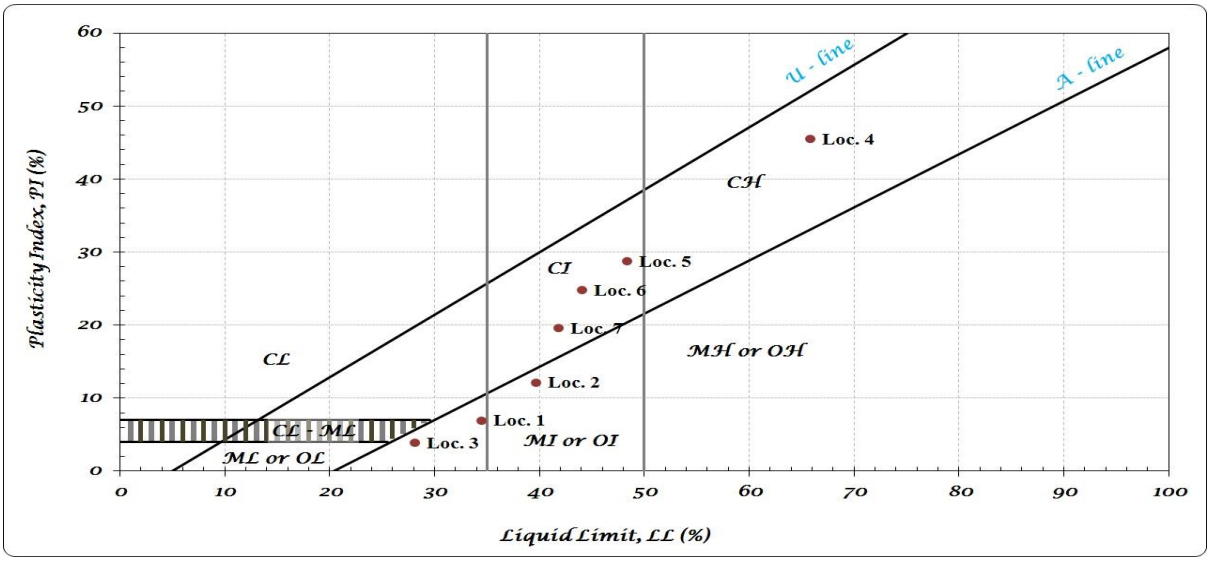

Fig 10: Soil classification Based on liquid Limit and Plasticity Index

Table 5: Classification of the Laterites using Unified Soil Classification System

Sample	Loc.1	Loc.2	Loc.3	Loc.4	Loc.5	Loc.6	Loc.7
Percent passing sieve No. 10	89.4	96.3	66.0	95.4	91.4	89.4	93.3
Percent passing sieve No. 40	65.7	69.6	36.1	81.8	67.7	66.1	63.6
Percent passing sieve No.200	42.1	48.3	17.4	71.7	52.4	48.2	46.9
Liquid Limit (%)	34.3	39.6	28.1	65.8	48.3	44.0	41.8
Plasticity Index (%)	6.90	12.20	3.90	45.53	28.85	24.80	19.60
Unified Soil Classification	SM	SM	SM	CH	CI	SC	SC
Type of Soil	Sand silty soil	Sand silty soil	Sand silty soil	Clayey soil of high plasticity	Clayey soil of medium plasticity	Sand clayey soil	Sand clayey soil

Base on the Unified Soil Classification System (USCS) results shown in Table 4.27: Loc.1, Loc.2 and Loc.3 soils are SM (sand silty soil); Loc.4 soil is CH (clayey soil of high plasticity); Loc.5 soil is CI (clayey soil of medium plasticity); and Loc.6 and Loc.7 soils are SC (sand clayey soils). The results of the USCS revealed sand in all the soils except Loc.4 and Loc.5 laterites.

4.4 AASHTO Soils Classification Results

The summary of the results of the classification of the laterites using AASHTO soil classification system is shown in Table 6

Table 6: Classification of Laterites using AASHTO Soil Classification System

Sample	Loc.1	Loc.2	Loc.3	Loc.4	Loc.5	Loc.6	Loc.7
Percent passing sieve No. 10	89.4	96.3	66.0	95.4	91.4	89.4	93.3
Percent passing sieve No. 40	65.7	69.6	36.1	81.8	67.7	66.1	63.6
Percent passing sieve No.200	42.1	48.3	17.4	71.7	52.4	48.2	46.9
Liquid Limit (%)	34.3	39.6	28.1	65.8	48.3	44.0	41.8
Plasticity Index (%)	6.90	12.20	3.90	45.53	28.85	24.80	19.60
Clay (%)	15.6	21.5	8	56.1	38.0	32.1	32.4
AASHTO Classification	A-4(0)	A-6(3)	A-1-b(3)	A-7(20)	A-7 (11)	A-7 (8)	A-7 (6)
Type of material	Silty soil	Clayey soil	Gravel and sand	Clayey soil	Clayey soil	Clayey soil	Clayey soil

On the basis of this classification system, Loc.1 soil is classified as A-4(0) (silty soil), Loc.2 is classified as A-6(3) (Clayey soil), Loc.3 is classified as A-1-b(3) (gravel and sandy soil), Loc.4 soil is classified as A-7(20) (clayey soil), Loc.5 soil is A-7(11) (clayey soil), Loc.6 soil is classified as A-7(8) (clayey soil) and Loc.7 soil is classified as A-7(6) (clayey soils).

5 Conclusions

Classification of the seven laterite deposits has been carried using unified and AASHTO soils classification system. By correlating the two classification systems, soils reveal by Unified soil classification system (USCS) is confirm by AASHTO classification system: AASHTO classification confirm silty soil reveal by USCS in Loc.1 soil sample as one of the major soil constituent; and AASHTO system also confirm sandy soil reveal by USCS system as the major constituent in Loc.3 soil. Further more, AASHTO classification system also confirm clayey soil reveal by USC system as one the major constituent in Loc.4, Loc.5, Loc.6 and Loc.7 soils. Only Loc.2 soil is not confirmed by AASHTO system because this system classified it as clayey soil which contradicts USCS which classified it as sand silty soil. It can be concluded that AASHTO and USCE give almost the same result; hence they can be used interchangeable.

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