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Study of Index Properties of Termite-Reworked Clay Soil from Sedimentary and Basement Areas of Ondo State, Nigeria: Implications on Engineering Applications

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Abstract: ***The index properties of termite-reworked clay soil from the sedimentary and basement areas of Ondo state, Nigeria were studied. Twenty samples of the soils were collected and analyzed in the laboratory using index tests techniques. The grain size results showed a well and gap-graded inorganic clay soils with higher percentage of fines. The liquid limits (LL%) from sedimentary and basement areas vary between 33.30 and 43.56% and from 36.3 to 49.7% respectively . These variations indicate 100% inorganic soil of kaolinite clay mineral. The plasticity index (PI) varies from 11.1 to 24.3 and from 13.2 – 24.1 for sedimentary and basement areas respectively. The soil samples were classified as CIP and A-2-4, A-2- 6, A-7-6 according to USCS, 2000 and AASHTO, 2004, systems and grouped in behaviour as V and VI for sedimentary and as CIP and CHP (A-7-5 and A-7-6) and grouped as VI and VII for basement areas respectively. These classifications and groupings portray the soils as Clay of medium to high compressibility. The studies also reviewed that the sedimentary termite reworked soil (STRWS) materials have the characteristic properties of high shearing strength and bearing capacity, presence of kaolinite clay minerals that make them highly hydrophobic. They also have low plasticity and compressibility as well as lowest swelling and shrinkage behaviour. Based on these characteristics the STRWS are more suitable for use as stabilizers in construction and for improvement in geotechnical properties of the soils. The basement termite reworked soil (BTRWS) soil though naturally suitableas material for dam construction, they can be applied in the area of environmental engineering such as in remediation, control of erosion, as well as suitable for the manufacture of burnt bricks due to their high fines, plasticity (13.2-24.1), high compressibility and low permeability. However, both STRWS and BTRWS soils need blending laterites in order to be suitable as foundation and road construction materials.***

Keywords: Index properties, liquid limits, plasticity index, Kaolinite, stabilizer

1. Introduction

Index properties of soil are useful in the identification and classification of soils. These properties indicate the type and conditions of the soil and provide a relationship with the structural properties. Soil index properties are used extensively by engineers to discriminate between the different kinds of soil within a broad category (ELE, 2013). The index properties of Lateritic-reworked (or termite reworked soil) soils from Ondo state are studied with the intent of knowing their index properties and their probable engineering applications. Lateritic-reworked soils (termite-reworked soils) are generally made up of sands grains and fine cellulose materials, which are coated with some sticky but readily hardening materials secreted by termites. The termitaria whose height may be up to 7m high may weigh up to 2.5tons (Atkins 1980). Termite hill- derived soils become as hard as rocks on drying and their strength increases with time. The clay from the termite mound is less prone to crack when compared with ordinary clay and it has low thermal conductivity and expectedly reduced solar heat flow and temperature fluctuation within an enclosure (Ndaliman, 2006). Adeyemi and Salami (2004) were of the opinion that there was a significant improvement in geotechnical properties of termite-reworked soils from Ago-Iwoye over those of nearby lateritic soils from identical depths. Oyediran et.al.. (2008) also recorded substantial improvement in engineering properties such as plasticity index, specific gravity and california bearing ratio (CBR) of termite-reworked lateritic soils over those of lateritic soils from Akungba-Akoko. Adeoye 2013 worked on the termite-reworked soils and migmatite-gneiss derived soil from Otun Agbakin near Moniya, Ibadan and found out that the mechanical stabilization showed remarkable improvement in both the CBR and unconfined compressive strength of samples.

Abe and Oladapo (2014) investigated the influence of activities of termite on the index properties (specific gravity, grain size distribution, consistency limits and linear shrinkage) of termite- reworked soils in Ado Ekiti and the results indicated that the activities of termites improved the index properties of the studied termite- reworked soils in relation to non-reworked soils. George (2009) examined anthill material to determine its use as a material for ceramic fabrication. He further examined the physical and chemical nature of clay samples with respect to their workability, shrinkage, strength, color and porosity. He concluded that all the anthill samples are suitable for the manufacture of burnt bricks. Akinola and Obasi 2004 stated that the properties of a soil are determined by the mineralogical composition, shape and size distribution of its component particles, their interactions with each other as well as water and dissolved salts. The type of clay that formed is not only a function of the nature of parent rock but also the intensity of weathering and the length of time during which it occurred.

Scholars such as Bayowa et al. 2014; Okunade 2007; Oladapo and Ayeni 2013; Owolabi and Talabi et al. 2013 have studied the engineering properties of termite-reworked soils around the States in Southwestern Nigeria and no attempt has been made to investigate the index properties of termite- reworked soil from different geological terrains of sedimentary and basement areas. Hence, the absence of the later forms the reasons for this research of using the index properties of the reworked soil to suggest areas of their engineering applications.

2. Geology of the Study area

The study area lies within latitudes 07°23′ and 07°52′N and longitudes 04°58′ and 05°31′E. The geology of Nigeria is dominated by sedimentary and crystalline basement complex rocks and this occurs in almost equal proportions. (Rahaman and Malomo, 1983; Shitta, 2007). The sedimentary is mainly upper Cretaceous -Recent in age while the basement complex rocks are Precambrian. The study areas fall into the sedimentary and basement rocks of Ondo State (Fig.1). The towns in the sedimentary section are Ode-Irele, Okitipupa, and Igbokoda and they are underlain by coastal plain sands typical of the coastal sedimentary basin of the eastern Dahomey basin (Rahaman 1988). The quaternary coastal plain sands of the eastern Dahomey basin constituted the major shallow hydrogeological units of the areas due to its porosity and permeability (Onwuka 1990; Omosuyi et al. 2008). The section that falls within the basement complex rocks of the study area comprises Akure and Akoko areas and they are underlain by the migmatite-gneiss-quartzite complex of the Basement complex. (Rahaman 1988). The Nigerian Geological Survey Agency (NGSA, 2006) suggested other distinguishing lithological units in the area to include granite-gneiss migmatite, quartz-schist, fine-grained quartz schist and undifferentiated schist as shown in Fig 1.

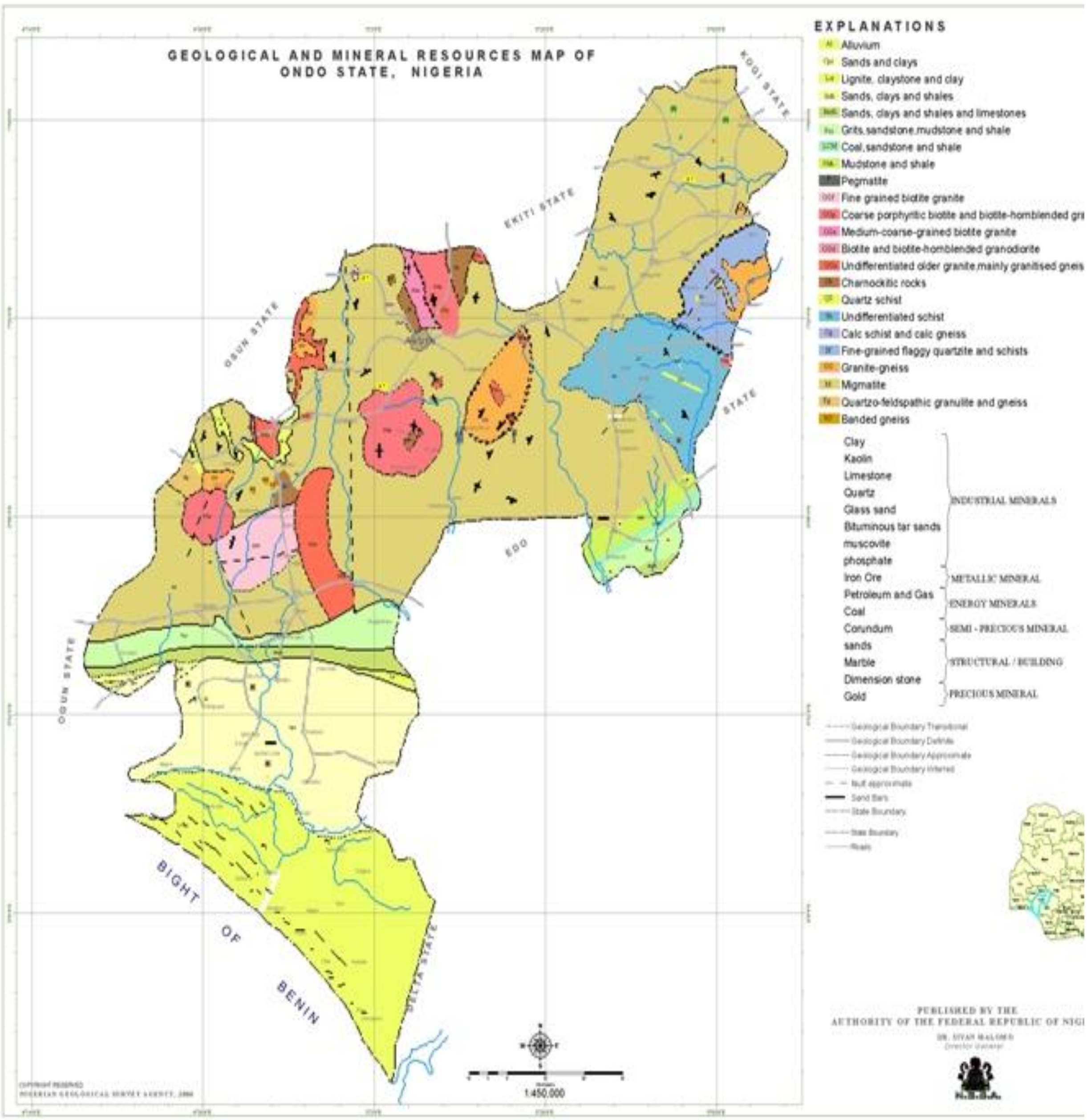

Figure 1: Geological Map of Ondo State (Adapted from NGSA, 2006)

3. Material and Methods

3.1 Sampling

The samples used for the analysis were collected from twenty (20) different locations within the study area (Fig. 2).

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 in-situ materials. The samples were sent to the geotechnical laboratory of the Federal University of Tech. Akure, for various laboratory tests.

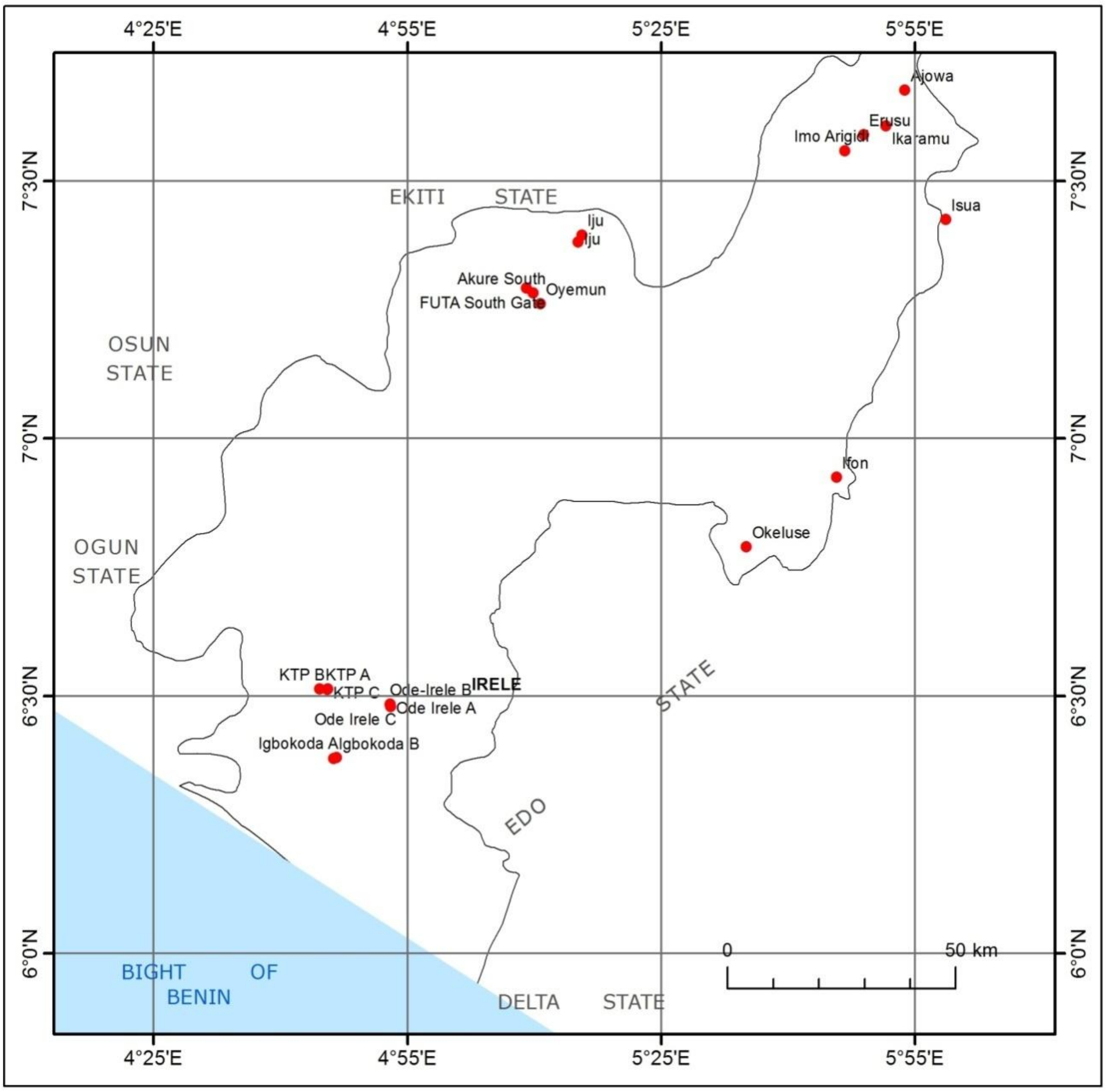

Figure 2: Map of Ondo State showing sample locations (red bullet)

3.1.2 Laboratory Test

The following laboratory tests were conducted on the samples: sieve analysis test, atterberg limit test, and hydrometer test respectively

3.1. 3 Particle Size Gradation

The particle size test of the soil samples was carried out on a mechanical sieve shaker. in accordance with wet sieving British Standard, BS 1377 [1990] test 7a standard. The sample materials were allowed to drain and 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 63 µm sieve. The percentage weight retained and the percentage passing in the sieves were determined. The percentage passing versus particle size distribution is plotted as shown in Figures 3a and 3b respectively.

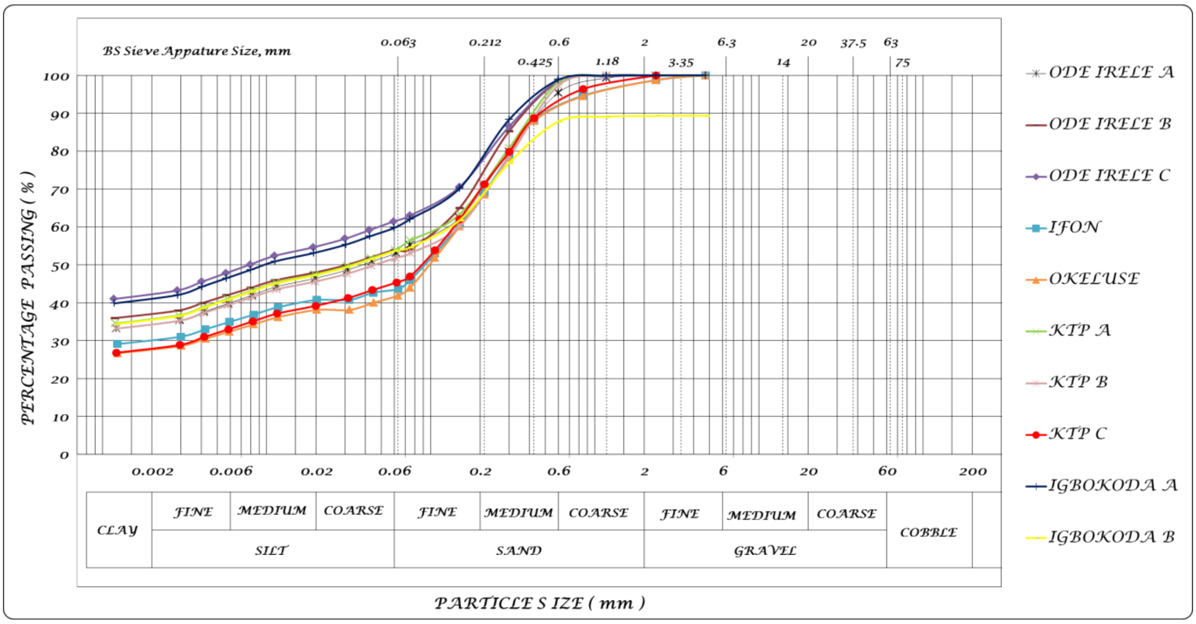

Figure 3a: Percentage passing versus Grain size distribution fraction for sedimentary termite -reworked clay soils

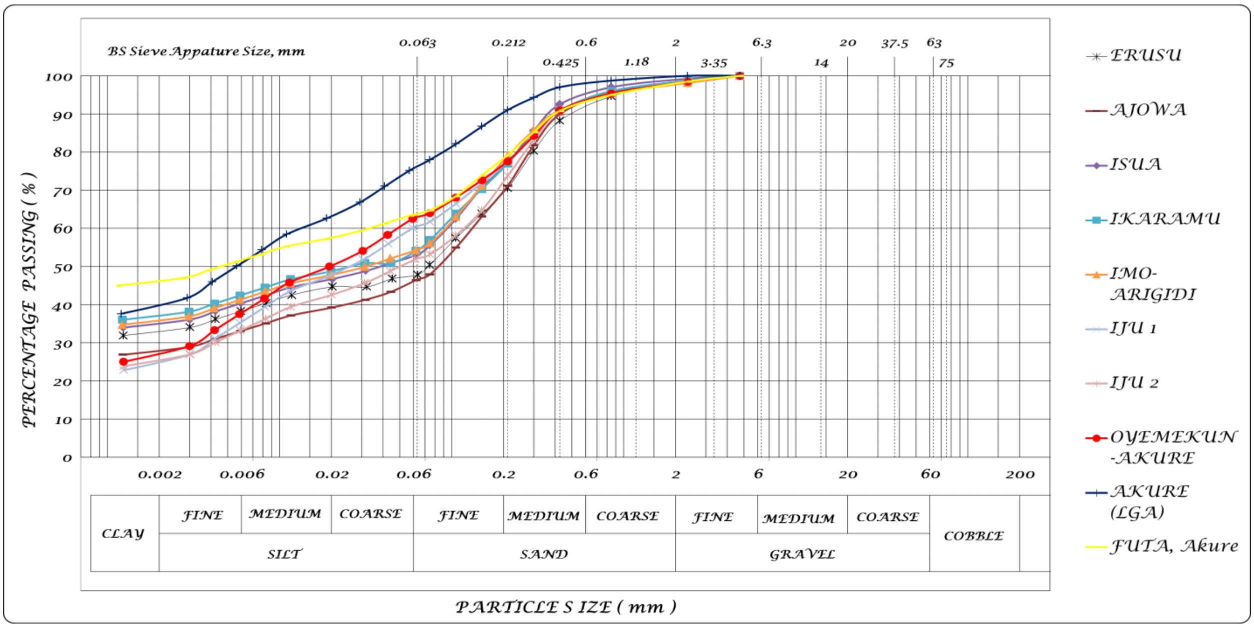

Figure 3b: Percentage passing versus grain size distribution fraction for basement rock termite-reworked clay soils

3.1.4 Atterberg Limits Test

The liquid limit was taken as the moisture content that correspond to 25 blows. The test for plastic limit determination was carried out in accordance with BS 1377 [1990] test 3 standard. 20grams of reworked -clay soil samples were 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 rolled between the fingers and a glass plate using steady pressure which reduced the diameter to about 3mm, the pressure being maintained until the thread crumbled. This crumbling point is the plastic limit.

4. Results and Discussion

Tables 1a and 1b present the results of the grain size fraction distribution, liquid limits and classification of the reworked -clay soils from the sedimentary and basement parts of the study areas.

Table 1A: Grain size fraction , Atterberg Limits and Soil Classifications of the studied Sedimentary Termiteria

Name	Gravel %	Sand %	Coarse Cont. %	Silts %	Clay %	Fines Cont. %	LL (%)	PL (%)	PI	SL (%)	LS (%)	AASHTO Class S** Soil Name GI	USCS & IAEG Classes S**	Soil Name	Behaviour group
KTP C	0.0	53.	53.1	18.8	28.1	46.9	43.5	22.4	21.1	9.1	9.3	A-7-6(0)	CL	CIP	Vi
KTP B	0.0	43.6	43.6	20.8	35.6	56.4	37.6	20.7	16.9	9.6	8.6	A-7-6(2)	CL	CIP	Vi
KTP A	0.0	43.6	43.6	20.8	35.6	56.4	38	24.2	13.9	6.8	12.9	A-7-6(3)	CL	CIP	Vi

Ode -Irele C	0.1	36.9	40.0	27.9	32.1	61.0	41.6	24.1	17.5	10.1	7.9	A-7-6(1)	CL	CIP	Vi
Igbokoda A	0.0	38.0	38.0	21.2	40.8	62.0	42.3	18.0	24.3	8.2	10.7	A-7-6(0)	CL	CIP	Vi
Igbokoda B	10.7	34.7	45.4	19.3	35.3	54.6	33.3	22.2	11.1	9.1	9.3	A-2-6(0)	CL	CLP	V
Ifon	1.2	52.9	54.1	15.6	30.3	45.9	34.2	17.5	16.8	12.5	4.3	A-2-6(0)	CL-	CLP	V
Ode-Irele A	0.2	44.6	44.8	43.5	11.7	55.2	37.5	24.2	13.3	12.5	4.3	A-7-6(0)	CL	CIP	Vi
Okeluse	1.2	54.8	56.0	16.1	27.9	44.0	33.3	18.3	15.1	12.5	4.3	A-2-4(0)	CL	CLP	V
Ode-Irele B	0.0	46.0	46,0	17.2	36.8	54.0	36.6	22.1	14.5	10.1	7.9	A-7-6 (1)	CL	CIP	Vi

The data are translated into Figures 3a and 3b for the sedimentary and basement rock areas respectively.Fig.3a shows a uniform curve that covers clay, silt, sand and the fines of gravel. The curve in the clay side is uniform and gap graded. The curve in Fig.b representing the basement part is well graded. The differences in the curves may have resulted from intense weathering experienced by the reworked clay soils in both terrains. Akinola and Obasi (2004) reported that the type of clay that formed is not only a function of the nature of parent rock but also the intensity of weathering and the length of time during which it occurred. The fine grained fractions dominate the composition of the studied soils, in comparison with coarse content fractions. Based on the Unified Soil Classification System (ASTM, 2000) soils with amount of fines that range between 0 - 5% are generally well-graded gravely class, while soils with amount of fines in the range of 5-15% are well-graded clayey sand or gravel. Soils with fines in the range of 15 -35% are said to be very clayey. In the present study, the fines fall above the range of 15-35% in the soil samples from both the sedimentary (44-63%) and basement (50.4-77.7%) parts and therefore are clayey. The gradation textures are related to the textural characteristics of the type of the parent rock such that well graded soils suggest decreasing degree of leaching and weathering whereas gap-graded soil suggests increasing degree of leaching and weathering due to fractional distribution with an absence of or bias towards a particular size (USC, 2000). This scenario implies that the sedimentary reworked clay soil (STRWS) has experienced high degree of weathering process which may have affected its deposition. It will be noted that sedimentary clay soils allows more flow of water in terms of permeability and drainage compared to basement reworked- clay soils (BTRWS) due to differences in the gradings.

Table 1B: Grain size fractions, Atterberg Limits and soil Classifications of the Studied Basement complex Termiteria

Name	Gravel %	Sand %	Coarse %	Silts %	Clay %	Fines %	LL (%)	PL (%)	PI	SL (%)	LS (%)	AAASHTO Class Soil Name (GI)	USCS & IAEG Classes Soil Name		Behaviour group
Imo Arigidi	1.9	42.1	44.0	19.9	36.1	56.0	48.2	24.2	24.1	8.7	10.0	A-7-6(3)	CL	C I P	Vi
Ikaramu	1.2	41.9	43.1	19.5	37.4	58.9	44.5	21.5	23.0	9.6	8.6	A-7-6(4)	CL	C I P	Vi
Iju	0.1	22.2	22.3	54.9	22.8	77.7	42.3	26.6	15.7	14.9	0.9	A-7-5(0)	CL	C I P	Vi
Iju	1.5	45.3	46.8	27.3	25.9	53.2	37.6	24.7	21.7	9.1	9.3	A-7-6(0)	CL	C I P	Vi
Oyemun	1.5	34.5	36.0	36.6	27.4	63.4	47.3	24.5	22.9	9.1	9.3	A-7-6(0)	CL	C I P	Vi
Isua	0.7	48.7	49.4	20.3	35.3	50.6	42.4	18.5	24.0	10.1	7.9	A-7-6(3)	CL	C I P	Vi
Ajowa	1.5	50.5	52.0	19.8	28.1	49.5	36.3	23.1	13.2	10.2	7.9	A-7-6(0)	CL	C I P	Vi
Akure	0.0	21.8	21.8	42.6	35.6	78.2	49.7	31.0	18.72	8.2	10.7	A-7-5(2)	CL	C I P	Vi
Erusu	1.2	48.3	49.5	17.2	33.2	51.7	40.1	22.2	17.9	10.6	7.1	A-7-6(1)	CL	C I P	Vi
FUTA	1.5	33.8	35.3	18.2	46.5	54.7	53.7	22.2	31.5	8.2	10.7	A-7-6 (10)	CH	CHP	Vii

The SRWS is 37-56% coarse with low fine contents (44 - 63%) while the BRWS is 21.8-52% coarse with high fine contents (50.4-77.7%). The present study shows that both the sedimentary termite -reworked clay soil (SRWS) and basement termite -reworked- soils (BRWS) have fine contents that exceeded the 35% maximum permissible grade proposed by Federal ministry of works and housing FMWH (1974) as very suitable as foundation materials. Soils with fines greater than 35% and coarse contents less than 65% suggest high amount of micas and feldspars that are associated with migmatite-gneiss of the study area (Mitchell 1993). The BRWS with higher fine content (50.4-77.7%) characterized by grit soils that are angular with flat faces and sharp edges will serve better as liner and remedial materials in environmental engineering compared to SRWS with 44 - 63% fines and high plasticity.

4.1 Consistency limits

Table 2 relates the results of the consistency limits (liquid limit and plastic limits) and their resulting inferred mineralogy. The ranges of the liquid limit (LL %) and the plasticity limits are presented in Table 2. The LL % of the SRWS varies between 33.30-43.5% while BRWS ranges from 36.3-49.7%. These ranges indicate 100% inorganic soil and a dominance of kaolinite clay minerals (Mitchell 1993).

Table 2: Consistency limits in relation to clay mineralogy of study soil.

Soil Type	Liquid Limit (L1) %	Inferred clay mineral(s)	Plastic Limit (PL)% Range	Inferred clay mineral (s)
SRWS	33.3 – 43.5	Kaolinite	17.5 – 24.20	Kaolinite
BRWS	36.3 – 53.70	Kaolinite	18.5 – 31.0	Kaolinite

Plasticity index (PI) values are in the range of 11.1 – 24.3 for SRWS and that of the BRWS are 13.2 – 24.1 respectively suggesting that the clays have low to intermediate plasticity values (Bell 2007). Mitchell 1993 proposed the ranges of liquid and plastic limits within which clay minerals would occur (Table 3). Since the ranges of the liquid limit (33.3-43.5) and the plastic limit (17.5-24.2) fall within the kaolinite range of 30-110 and 25-40 respectively for both the SRWS and BRWS soils, it suggests the absence of illite and mortmorinollite clay minerals in the reworked clay soils of both terrains.

Table 3: Values of plasticity parameters for pure clays (Mitchell 1993)

A	Standard	Standard	D	E
Mineral	Liquid limit %	Plastic limit %	Liquid limit %	Plastic limit %
Montmorillonite	100-900	50-100	33.3-43.5	17.5-24.2
Illite	60-120	35-60		
Kaolinite	30-110	25-40		

D=Liquild limits , E = Plastic Limits of the studied samples

Ola (1983) used the classification of the plasticity index values to relate the swelling potentials stating that clay soils with less than 25% of plasticity index tend to possess low to medium swelling potential. This proposal gives the engineer the idea to detect the possibility of swelling and shrinkage as well as differential settlement of soil materials. Going by this therefore, many of the samples in both the SRWS and BRWS clay soils fall into the A-7-6 soil class with clay of intermediate plasticity (CI) respectively according to American Association of State Highway and Transportation Officials (AASHTO, 2004) and International Association of Engineering Geologist (IAEG, 1981) classifications respectively. However, in the study areas, three samples from SRWS soil fall into A-2-6 soils class with clay of low plasticity (CL). Clays of low plasticity, medium and high plasticity are assigned V, V1 and V11 in the behavior groups respectively (Table 4). Clays of group V are those whose plasticity index are less than 15 (PI< 15) and they include silt clay, sandy gravelly clay of low plasticity. Clays of group V1 are of medium plasticity whose plastic index is greater or equal to 15 (PI ≥15) and they are the silty sandy or gravelly clays while the clay that fall into group V11 are of high plasticity. Thus, three samples fall in group V, sixteen in group V1 while one soil sample falls in group V11 respectively. The SRWS soils that have three samples that fall into the A-2-6 and seven A-7-6 classes with a low plasticity index (0 – 3) values are more suitable as sub-grade materials for road construction and foundation projects in contrast with the BRWS soils where all samples fall in A-7-6 class with a plasticity index range of (0-10) (Table 2B). The much greater group index value indicates low load carrying capacity of the clay soils, suggesting that the SRWS clay soils have better bearing capacity materials in relation to the BRWS clay soils. The correlation of the behavior groups with standard characteristics of foundation materials, compacted fill materials and soils for use as fill materials for rolled earth dams in Tables 4 – 6 respectively, reveal that the BRWS clay soils show more resistance to failure in piping and cracking due to their high plasticity when compared to the SRWS clay soils. In addition, the application of basement complex termitaria clay materials in environmental engineering areas of remediation, erosion control are due to their low permeability, high compressibility and high fine content characteristics. The SRWS clay soil is preferred to BRWS clay soils as foundation materials because of their high shearing strength and bearing capacity.

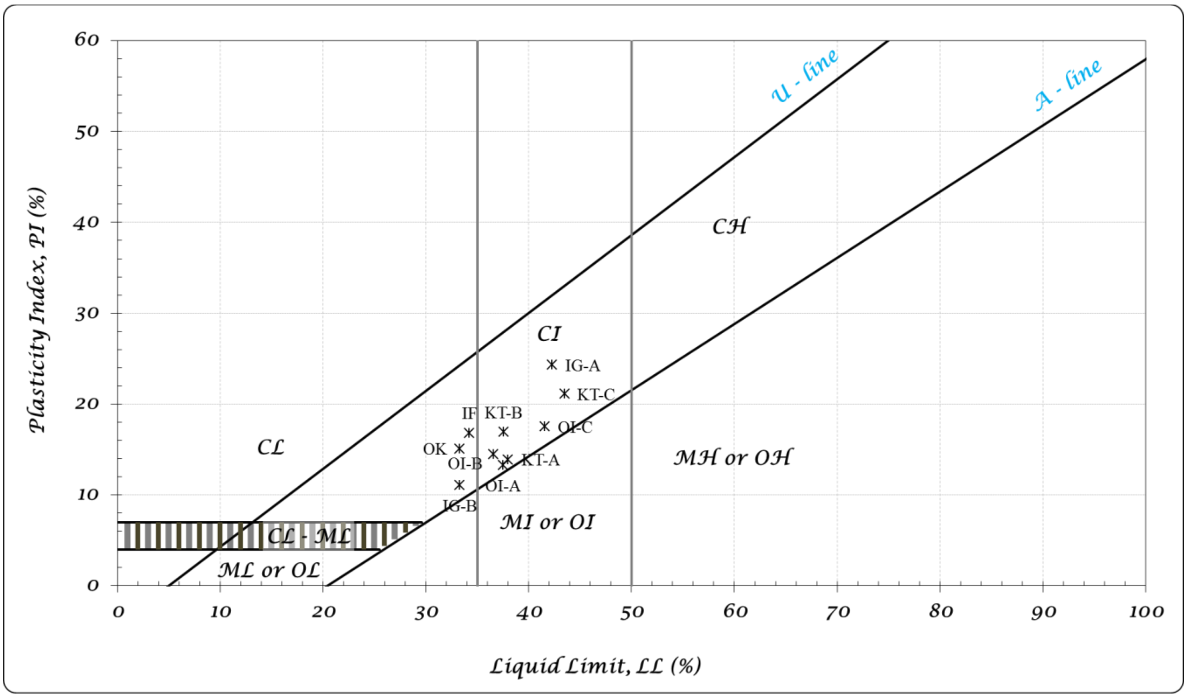

Figure 4a: Plot of plasticity index versus Liquid limit for the sedimentary reworked clay soil of studied sample

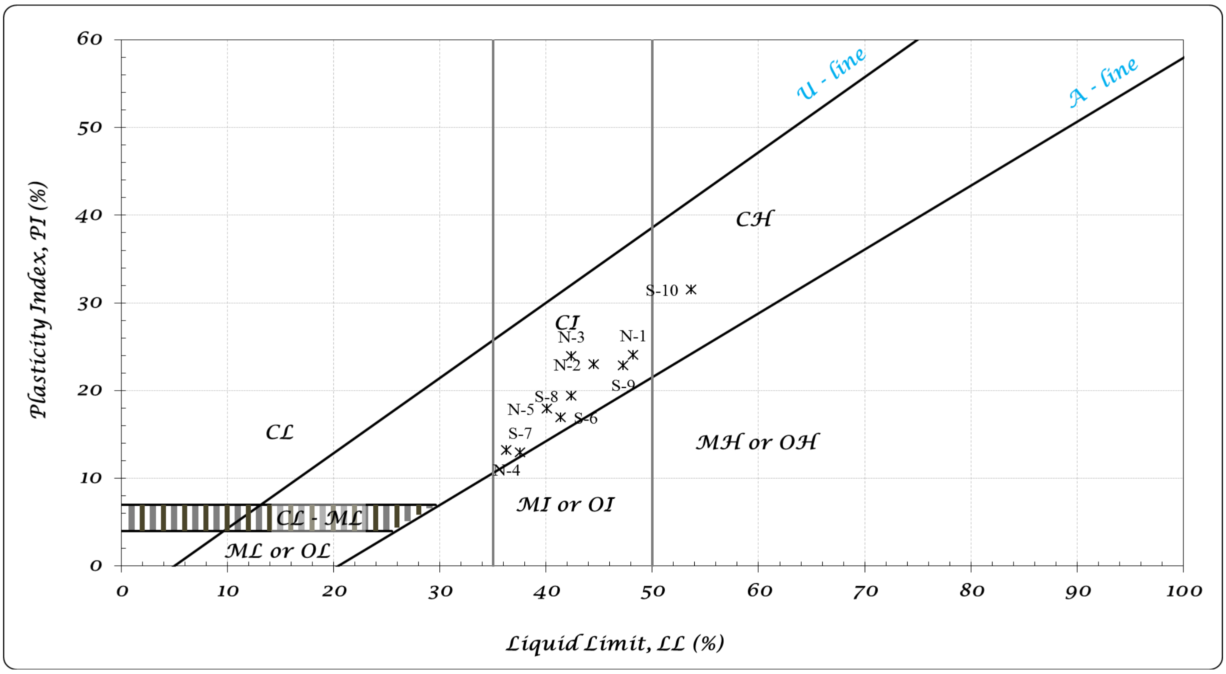

Figure 4b: Plot of plasticity index versus Liquid limit for the basement reworked clay soil of studied sample

Table 4: Working classification of soils for use as fill materials for rolled earth. (USCS, 2000)

Working classification of soils for use as fill materials for rolled earth dams					
Major Divisions			Symbol	Typical Name	Behavior
Fine Grained Soils $d_{50} \leq$No 200 Mesh (0.074mm) Coarse Grained Soils $d_{50} >$ No. 200 Mesh (0.074mm)	Sands and Gravels Silts and Clays	Clean	GW	Well graded gravel; sandy gravels	I
			GP	Poorly graded gravels; sandy gravels	
			SW	Well graded sands; gravelly sands	
			SP	Poorly graded sands; gravelly sands	
		With Clay Fines	GC	Clayey gravels; sandy, clayey gravels	ii
			SC	Clayey sands; gravelly, clayey sands	
		With Silts Fines	GM	Silty gravels; sandy, silty gravels	iii
			SM-1	Coarse silty sands	
			SM-2	Fine silty sands	
		LL < 50	ML	Silts: rock flour; ash; very fine silty sands; sandy, clayey silts	iv
			CL-1	C lays of low plasticity; silty clays; sandy, gravelly clays (PI < 15)	V
			CL-2	Clays of medium plasticity; silty, sandy, or gravelly clays(PI ≥15)	Vi
		LL ≥ 50	CH	Clay of high plasticity; fat clay	Vii
			MH	Elastic silts; micaceous and diatomaceous silt	Viii
		Organic	OL	Organic silts and clays	ix
			OH	Organic silts and clays	

Table 5: Characteristics of Compacted Fill Materials (USCS, 2000)

Behaviour group	Relative Resistance to Failure (1) Greatest (6) Least			Relative Characteristics	
	shearing	piping	cracking	permeability	Compressibility
1	2	3	4	5	6
I	1	-	-	High	Very Slight
Ii	3	3	4	Low	Slight
Iii	2	5	3	Medium	Slight
Iv	3	6	6	Medium	Slight to medium
V	4	4	5	Low	Medium
Vi	5	2	2	Low	Medium to High
Vii	6	1	1	Low	High
Viii	6	variable	variable	Medium to Low	Very High
Ix	6	variable	variable	Medium	Very High

Table 6: Unified Classification and Properties of Soils. (USCS, 2000)

Typical Names	Shear strength	Compressibility	Workability as Construction Material	Permeability			USCS
				When compacted	K Cm. Per Day	K Ft. Per Day	
Well graded gravels, gravel - sand mixtures, little or no fines.	Excellent	Negligible	Excellent	pervious	K > 10^{-2}	K > 30	GW
Poorly graded gravels, gravel – sand mixtures, little or no fines.	Good	Negligible	Good	Very Pervious	K > 10^{-2}	K > 30	GP
Silty gravels, gravel-sand-silt mixtures.	Good to Fair	Negligible	Good	Semi-pervous to impervous	K = 10^{-3} to 10^{-6}	K = 30 To 3 x 10^{-5}	GM
Clavey gravels, gravel-sand-clay mixtures.	Good	Very Low	Good	impervious	K = 10^{-6} to 10^{-8}	K = 3 x 10^{-3} To 3 x 10^{-5}	GC
Well graded sands, gravelly sands, little or no fines	Excellent	Negligible	Excellent	Pervious	K > 10^{-3}	K > 3	SW
Poorly graded sands, gravelly sands, little or	Good	Very Low	Fair	Pervious	K > 10^{-3}	K > 3	SP
Silty sands, sand-silt mixtures	Good to Fair	Low	Fair	Semi-pervious to impervious	K = 10^{-3} To 10^{-6}	K = 3 to 3 x 10^{-3}	SM
Clayey sands, sand-clay mixtures	Good to Fair	Low	Good	Impervious	K = 10^{-6} to 10^{-8}	K =3 x 10^{3} to 3 x 10^{-5}	SC
Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Fair	Medium To High	Fair	Semi-pervious to impervious	K = 10^{-3} to 10^{-6}	K = 3 to 3 x 10^{-3}	ML
Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, lean clays	Fair	Medium	Fair	impervious	K = 10^{-6} to 10^{-8}	K = 3 x 10^{-3} To 3 x 10^{-5}	CL
Organic silts and organic silty clays of low plasticity	Poor	Medium	Fair	Semi-pervious to impervious	K = 10^{-4} to 10^{-6}	K = 3 x 10^{-3} To 3 x 10^{-3}	CL
Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Fair to Poor	High	Fair	Semi-pervious to impervious	K = 10^{-4} to 10^{-6}	K = 3 x 10^{-1} To 3 x 10^{-3}	MH
Inorganic clays of high plasticity, fat clays	Poor	High to Very High	Poor	Impervious	K = 10^{-6} to 10^{-8}	K = 3 x 10^{-3} To 3 x 10^{-5}	CH
Organic clays of medium to high plasticity, organic silts.	Poor	High	Poor	Impervious	K = 10^{-6} to 10^{-8}	K = 3 x 10^{-3} To 3 x 10^{-5}	CH
Peat and other highly organic soils	Not Suitable for Construction						Pt

5. Conclusion

The index properties of termite-reworked soils in the sedimentary and basement areas of Ondo State are evaluated. The results of the tests revealed that the lateritic-reworked soils are inorganic clay of low to medium plasticity with predominantly kaolinite minerals. The SRWS soil samples were classified as CIP and falling into the classes of A-2-4, A-2- 6, A-7-6 while their behaviors are grouped as V and VI (Table 3). The basement area is classified as CIP and CHP and falling into the classes of A-7-5, A-7-6 and grouped as VI and VII. This classifies the soils as clay of medium to high compressibility. Based on these classifications and groups, both the basement and sedimentary termitaria clay soils are generally unsuitable as foundation and road construction materials unless they are modified using laterites. However, they are suitable materials in dam construction and in environmental engineering such as remedial and lining materials. The SRWS materials have the characteristic properties of good shearing strength, bearing capacity, presence of kaolinite clay minerals that make them highly hydrophobic, low plasticity and compressibility and lowest swelling and shrinkage behaviour that make them more suitable as foundation and road construction materials.

However, the BRWS soil though naturally suitable as mater ial for dam construction, they can be applied in the area of e nvironmental engineering such as in remediation, control of erosion, as well as suitable for the manufacture of burnt bricks due to their high plasticity, high fine contents, high compressibility and low permeability.

References

[1] ELE International (2013): Chartmoor Road, Chartwell Business Park, Leighton Buzzard, Bedfordshire, LU7 4WG
[2] Atkins, M D.(1990):Introduction to behaviour. Neew York, Macmillan. 237pp.
[3] Ndaliman, (2006) also investigated on how additive such as graphite, asbestos varied at different percentage affect refractory properties of pure termite hills..
[4] Adeyemi, G. O. and Salami, R. (2004). Some geotechnical properties of two termite-reworked lateritic soils from Ago-Iwoye, Southwestern *Nigeria*, Mineral Wealth: The quarterly publication of the Scientific Society of the Mineral Wealth Technologists, Athens. Vol. 133, 35 – 41.
[5] Oyediran, I. A. Adeyemi, G. O. and Oguntunwase, E. O. (2008). Influence of Termite activities on the geotechnical properties of some lateritic soils in parts of Akungba-Akoko Southwestern Nigeria. Mineral Wealth, No. 148, 17 – 24.
[6] Adeoye, A. S. (2013). Mechanical stabilization of a migmatite-gneiss derived lateritic soil from Ibadan,

Southwestern Nigeria. Unpublished M.Sc., (Geology) project, University of Ibadan, Ibadan, Nigeria.

[7] Abe, O.E. and Oladapo, S.A (2014). “Investigation of the Index Properties of Lateritic Soil Reworked By Termite for Road Construction”, International Journal of Engineering Research & Technology (IJERT), Vol. 3 Issue 4, 1032-1034.

[8] DeGraft-Johnson, J.W.S. and Bhatia. , H.S. (1970) :Definition, formation and classification of lateritic soils Proceedings of the Specialty Session on Engineering Properties of Lateritic Soils. Seventh International Conference of soil mechanics and foundation Engineering. Asian Insttute of Technology, Bangkok. Thailand, 14 - 43.

[9] Akpokodje, E.G., Etu- Efeotor, J. O. and Olurufemi, B. N. (1991): The compositional and physical of some ceramic and pottery clays of South Eastern Nigeria, J. of Mining and Geology, vol.27 (1), 1-8.

[10] Akinola, O. O., Obasi, R. A. (2014). Compositional Characteristics and Industrial Potential of The Lateritic Clay Deposit In Ara-Ijero Ekiti Areas, Southwestern Nigeria. International Journal of Scientific & Technology Research, Volume 3, 8:305 -311.

[11] Bayowa, O.G., Olorunfemi, O.M., Akinluyi, O. F., & Ademilua, O.L. (2014). A Preliminary Approach to Groundwater Potential Appraisal of Ekiti State, Southwestern Nigeria. International Journal of Science and Technology (IJST). Vol. 4, No. 3. 48-58.

[12] Okunade, E.A. (2007). Engineering Properties of Lateritic Adobe Bricks for Local Building Constructionand Recommendations for Practice. Journal of Engineering and Applied Sciences. Vol. 2(9). 1455-1459.

[13] Oladapo, M.I. and Ayeni, O.G. (2013). Hydrogeophysical Investigation in Selected Parts of Irepodun /Ifelodun Local Government Area of Ekiti State, Southwestern Nigeria. Journal of Geology and Mining Research. Vol. 5(7). 200 – 207.

[14] Rahaman, M. A., Malomo, S. (1983). “Sedimentary and Crystalline Rocks of Nigeria”, in “Tropical soils of Nigeria in engineering practice”, edited by S. A. Ola, A.A. Balkema/Rotterdam, 17-38

[15] Shitta, K. A. (2007).“Lithostratigraphy of Nigeria–an overview”, Proceedings of 32nd workshop on Geothermal Reservoir Engineering, Stanford University - Stanford, California, 1–9.

[16] Rahaman, M.A. (1988): Review of the basement geology of southwestern Nigeria. *In*: Kogbe, C.A., (ed) Geology of Nigeria, Rock View (Nig.) Limited, Jos, Nigeria, pp.39-56.

[17] Onwuka MA (1990. Groundwater Resources of Lagos State. M.Sc Thesis (unpublished), University of Ibadan.

[18] Omosuyi G. O, Ojo J. S, Olorunfemi M. O (2008) Geoelectric Sounding to Delineate Shallow Aquifers in the Coastal Plain Sands of Okitipupa Area, Southwestern Nigeria. Pacific Journal of Science and Technology. 9(2):562-577.

[19] Nigeria geological survey agency. (2006): Geological of Ondo State published by the authority of the Federal Republic of Nigeria.

[20] British Standards 1377 (1990). Methods of tests for soils for civil engineering purposes, London

[21] Federal Ministry of Works and Housing (1974): General Specifications for Roads and Bridges”, Volume II.145-284. Federal Highway Department: Lagos, Nigeria. . Vol.2, 305p

[22] Mitchell, J.K (1993). Fundamentals of soil behavior (3rd ed.). John Wiley and Sons, Inc

[23] Bell, F.G (2007): Engineering Geology 2nd Edition, Butterworth-Heinemann Publishers, Oxford. 581p.

[24] Ola, S.A.(1983): Geotechnical Properties and behavior of some Nigerian lateritic Soils In: S.A Ola Ed.Tropical Soils of Nigeria In Engineering Practice. A.A. Balkama Netherlands. Pp.61-84.

[25] AASHTO (2004). Standard Specifications for Transportation Materials and Methods of Sampling and Testing (24rd ed.), American Association of State Highway and Transportation Officials, Washington, D.C

[26] USCS, (2000): ASTM Standard D2487, 2000, "Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)," ASTM International, West Conshohocken, PA, 2000,DOI: 10.1520/D2487-00, www.astm.org.