ISSN - 2277 - 0593
© UNAAB 2010

Journal of Natural Sciences, Engineering and Technology

PLASTICITY AND COMPRESSIBILITY CHARACTERISTICS OF LATERITIC SOIL FROM SOUTHWESTERN NIGERIA

B.S. BADMUS

Department of Physics, College of Natural Sciences, University of Agriculture, Abeokuta, Nigeria.

E-mail: badmusbs@yahoo.com **Tel:** +2348033378307

ABSTRACT

Plasticity index and coefficient of compressibility amongst other characteristics were determined for some lateritic soil samples of Southwestern Nigeria with a view to establishing the relationship between their plasticity and compressibility as well as predicting their in-situ compressibility and also determine the effect of the parent rocks on the plasticity and compressibility. Two study areas were chosen in Ibadan, Southwestern Nigeria where ten disturbed and ten undisturbed samples each were collected. The disturbed samples were subjected to a number of geotechnical tests: grain size, distribution analysis, specific grant and consistency test. The undisturbed samples were subjected to consolidation test. The study revealed the rock type in study area A to be quartzschist and area B to be granitic. The specific gravity of the soil grains ranged between 2.48 and 2.72; while the plasticity index value was between 9.7 and 21.4%. Coefficient of consolidation ranged between 29.39mm^2/min and 32.56mm^2/mm with coefficient of volume compressibility between 1.08 x10^{-3} m^2/KN and 1.94 x10^{-3}m^2/KN. The soil samples were generally well-graded reddish brown, sandy-silt-clay of medium plasticity and compressibility with dominant kaoline clay mineral in the quartzschist derived soil while the dominant clay mineral in the granite derived soil is illite. The most influenced parameter of the parent rocks was the coefficient of compressibility, which revealed the samples of the two study areas to be suitable for construction work as well as landfill site with little compaction.

Keywords: Lateritic, compressibility, plasticity, grain size, and clay.

INTRODUCTION

The most common materials used for construction are lateritic soils because they occur naturally with intense weathering (in the tropics) and there is lack of good quality crushed aggregate as well as economically attractive. Lateritic soils are found in the tropical environment where there is an intense chemical weathering and leaching of soluble minerals. Laterites are reddish brown, well graded and sometimes extend to depth of several tens of metres. They are found almost everywhere in the tropics with wide applications in the construction industries. This makes the study of the characteristic important in the areas of consistency limits, grain size distribution, permeability compaction, consolidation and shear strength. A lot of research activities have gone on lateritic soils but little emphases have been laid on the relationship between plasticity (consistency limits) and compressibility characteristics. Negligence on the part of construction engineers have led to uncountable road and structural failures within the sub-Sahara Africa. Ashworth (1966) revealed that lateritic soils are gap-graded with deficiency in sand and silt-size particles.

Gidigasu (1972) worked extensively on lateritic soils of Ghana and concluded that laterite was derived from chemical and mechanical disintegration of the parent materials resulting into concentration of iron and aluminum oxides. Ola (1974) investigated stabilization problems associated with laterite and the modified result is used in production of blocks. Balogun (1982) investigated some physical, geochemical and geotechnical properties of laterite of Shagamu, Southwestern Nigeria; this he found to have significant difference in some index properties.

Adeyemi *et al.* (1990) worked on some index properties and crushing strength of three Southwestern Nigeria lateritic clay deposits with the aim of seeing how the materials could be used for bricks. The result of their findings showed that firing increases the strength tremendously. Adeyemi (2002) investigated the geo-technical properties of lateritic soil developed over quartzschist in Ishara area, Southwestern Nigeria and showed the major mineral clay to be kaolinite with a subordinate amount of illite and montomorillonite.

MATERIALS AND METHODS

Location of the study areas

Two locations within the city of Ibadan were chosen for this research work. The first was within the University of Ibadan, Southwestern Nigeria with latitude between 7^0 27'N and 7^0 29'N, longitude between 4^0 21' E and 4^0 23'E tagged as study area A (Figure 1). The second location was around Adegbayi area along Ibadan –Ile-Ife road with latitude between 7^0 36' N and 7^0 38'N, longitude $4^0$27'E and $4^0$29'E tagged study area B (Figure 2).

Field Technique

A total of forty samples were collected with twenty disturbed and twenty undisturbed from the two study areas, University of Ibadan and Adegbayi. The sampling was done within an area of $10m^2$ at each location. The undisturbed soil samples were collected through the use of core cutters of about 150mm in length and 100mm in diameter. The core cutters were hammered into the borrow pit of about 0.5m to 1.0m depending on the topography and the soil profile in the area. The disturbed samples were collected after the collection of the undisturbed samples. Rock samples were also collected from each location to prepare thin section which will give the mineralogical composition of the rocks. The lateritic soil samples collected were soft, cohesive and wet in nature. All samples were reddish brown in colour, collected fresh and not weathered. For sample preparation, the undisturbed samples were collected in a polythene bags to prevent the exchange of moisture content between the soil and the atmosphere. The undisturbed samples were prepared for consolidation tests while the disturbed samples were air-dried to expel the in-situ moisture content, this was done for a period of time, depending on how wet the samples were.

Laboratory Analyses

The laboratory analyses were grouped into two: classification test for grain size distribution and consistency limits; consolidation test for co-efficient of consolidation and co-efficient of volume compressibility.

Grain size analysis involves two methods

Mechanical and Hydrometer Analyses, which require knowledge of the specific gravity of grains. For wet sieving procedure, 500g of air-dried soil samples was soaked in 2g of

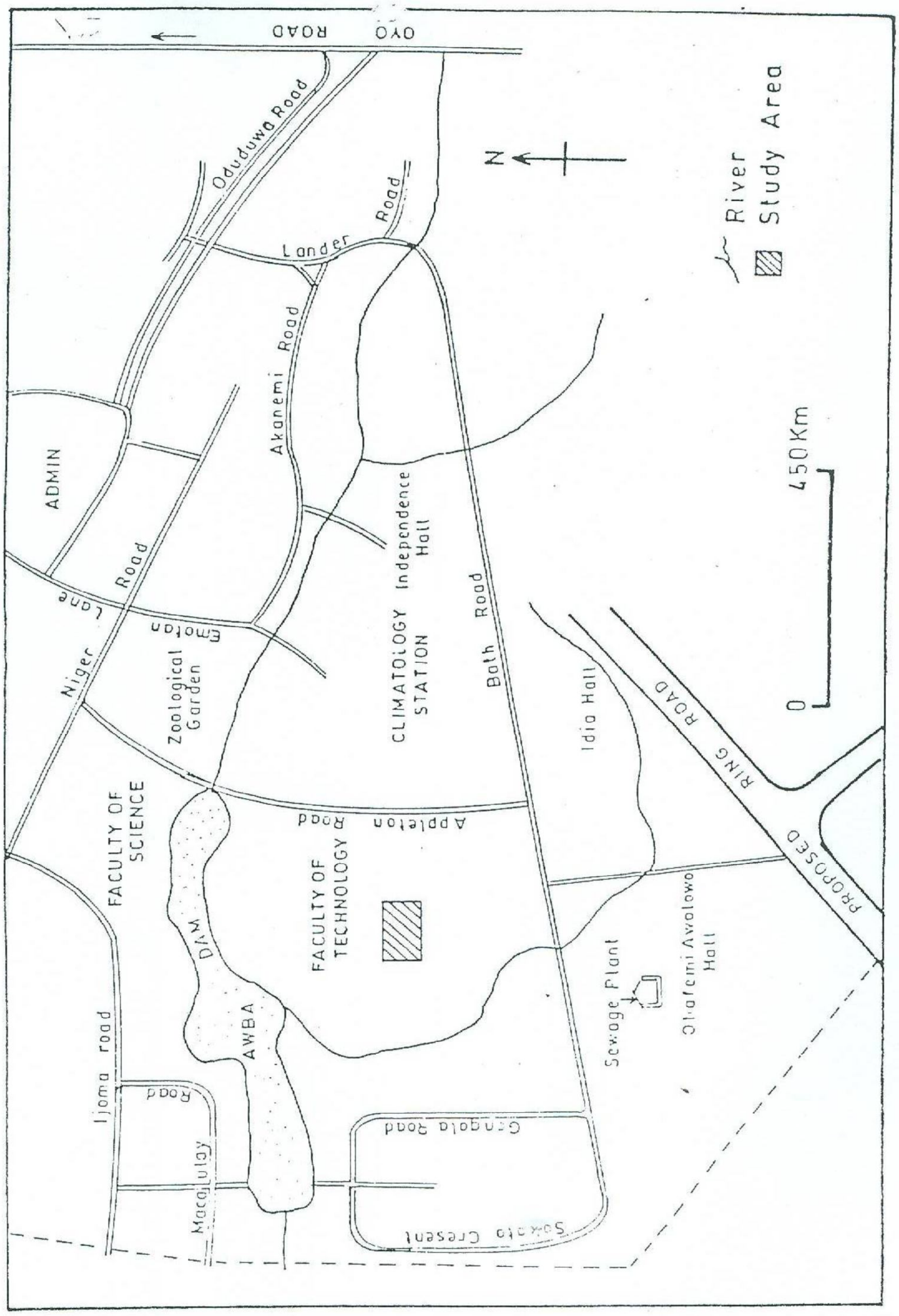

Figure 1: Location Map Showing Study Area A

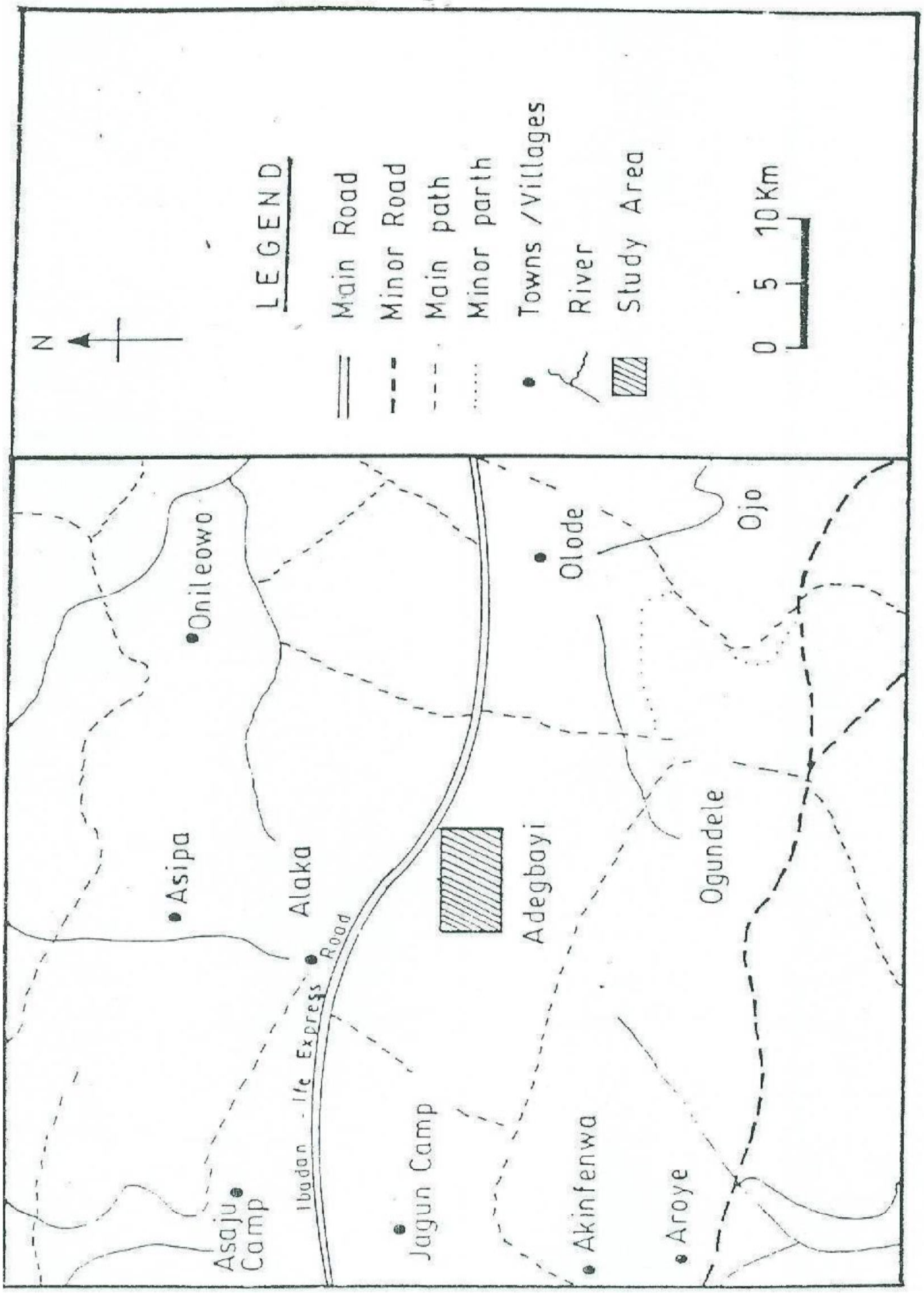

Figure 2: Location Map Showing Study Area B

calgon with 1 litre of water (sodium hexa-metaphosphate). This solution was then stirred and left overnight. The soil sample was washed under tap water for a period of 24 hrs until the water coming out became clean. This was done to separate silt and clay fraction from the coarse fractions, using 0.075mm sieve. These separated coarse fractions were oven-dried for about 24hrs at about 110°C; then dry-sieved using a set of sieves, mechanical shaker, weighing balance sensitive to 0.01g and sieve brush. The sieves were arranged in order of increasing mesh sizes with the smallest at the bottom and the largest at the top. The oven-dried soil was poured into the stack of sieves and transferred into the shaker, which operated for about ten minutes.

For Hydrometer Analysis

This utilizes the relationship between settling velocity of spherical particle, viscosity of the fluid and the specific weight (density) of the particle using Stoke's law:

$V \propto D\,(\delta s - \delta w)\,/\mu$, for particles with diameters between 0.002 and 0.2mm. Some substantial qualities of particles are oven-dried and can pass through 0.063mm at a temperature of 100°C and 110°C. 50g of the oven-dried soil was pulverized and poured into one of the measuring cylinder mixed with 2g of calgon and 1 litter of distilled water. The mixture was shaken vigorously until a uniform suspension was formed. The hydrometer was immediately inserted into the cylinder and timed immediately at 15sec, 30sec, 1min, 2mins, 4mins, 8mins, 15mins, 30mins, 1hr, 2hrs, 4hrs and 24hrs. Fine particle sizes were determined using the Stoke's equation.

Specific Gravity

This is the measure of the density of a soil relative to that of water. It is a means of identification and evaluation of lateritic soils as it relates to mechanical strength classification (De-Graft Johnson *et. al.,* 1972). 50g of the soil sample that can pass through sieve 0.425mm was added to the pycnometer, weighed and recorded as M_2. Sufficient air-free distilled water was added to the soil sample in the bottle and shaken to eliminate air indirection. The bottle (and its content) was weighed and recorded as M_3. The pycnometer was later filled with distilled water and weighed as M_4. M_1 is the weight of the pycnometer. Mathematically, the specific gravity was calculated using: $M_2 – M_1 / (M_4 – M_1) – (M_3 – M_2)$.

Plastic Limit

This is the moisture content at which the soil can no longer behave like a plastic material; the soil can be rolled into a thin thread without breaking up. The soil samples were air-dried, pulverized and passed through a sieve slot 0.425mm, mixed with water to form a homogenous paste. This paste was rolled into balls forming thread of about 3mm in diameter. The weight of the thread was determined and transferred into an oven of 100°C – 110°C for 24 hrs. The thread was re -weighed after removing it from the oven. Plastic limit was calculated from the expression: $\frac{(a-b)}{a} \times 100$ where a = wet weight of thread, b = dry weight of thread.

Consolidation Test

This test was carried out to establish the co-efficient of consolidation and co-efficient of volume compressibility. Coefficient of consolidation can be used to estimate the rate of settlement of any structure built on a compressible soil deposit while coefficient of volume compressibility is used to estimate the amount of settlement of the structure. Consolidation test is usually done in the laboratory using it Oedometer. Coefficient of consolidation C_v was calculated using the equation: $C_v = \pi d^2/4t_i$ where d = thickness of the original sample/2, t_i = time/ settlement. For coefficient of volume compressibility $M_v = -\frac{dh}{dp} \times \frac{1}{h}$, where dh = change in thickness, dp = change in pressure, h = average of h_1 and h_2 (thickness of samples). Knowing the C_v and M_v, we can now estimate the coefficient of permeability K for the sample: $K = C_v M_v dw$, where dw = unit of weight of water. The amount of settlement, S, of structures in a compressible soil deposit is estimated from M_v as: $S = M_v\ dp\ h$, where

h = thickness of compressible soil layer, dp = expected stress from the structure.

RESULTS AND DISCUSSION

Grain Size Distribution

The samples from the quartz schist based soil of the study area A showed greater amount of fines ranging from 40 to 55% with an average value of 46.8% while sample from granite based soil of study area B range between 30 and 47% with an average value of 38.6%. These samples show greater amount of coarse fraction between 53 and 70% with an average value of 61.4% (Table 1). This showed that the soils from both study areas are generally well-graded, reddish-brown, sandy–silt–clay soils. The lower the clay size fraction, the higher the coarse fraction and the better the parent rock. The soils from study area B, derived from granite showed that granite is a better construction material when compared with quartzschist.

Specific Gravity

The values for the quartzschist derived soil ranges between 2.6 and 2.72 with an average value of 2.66 while those of the granite derived soil is between 2.48 and 2.70 with an average value of 2.61 (Table 1). Average specific gravity for both study areas fell within the range specified by De Graft Johnson, 1969 for lateritic soil, and of course the higher the specific gravity, the higher the degree of laterization, provided the soils are from the same parent material.

Plastic Limit

The plastic limit values obtained from quartzschist derived soil ranged between 21.10% and 28.92% with an average value of 25.38%; while those of the granite derived soil range between 19.81 and 26.84% with an average value of 22.96% (Table 1).

Plastic Index

The plastic index values of the soil samples from the study area A ranged between 9.4 and 19.38 with an average value of 15.3% while in area B, the range is between 14.19 and 21.44% with an average value of 18.14%. Soil samples from study are B derived from granite had higher average plasticity index value than those derived from quart schist in the study area A (Table 1).

Coefficient of Consolidation C_v

These values range between 29.39 and 32.56mm^2/min for the soil analysis in study area A with an average value of 30.87 mm^2/min while in study area B, coefficient of consolidation ranges between 30.68 and 32.56mm^2/min with an average value of 31.52mm^2/min. Soil samples from study area B have higher average rate of settlement and due to the low values of consolidation co-efficient observed in both study areas, the soils are suspected to be good foundation

Table 1: Summary of Grain Size Analyses, Plastic Limit Values, Plasticity Index Values, Specific Gravity, Coefficient of Consolidation and Coefficient of Volume Compressibility

Samples	Gravel %	Sand %	Silt %	Clay %	Amount of Fines	Plastic Limit Values				Plasticity Index Values			Specific Gravity	Coefficient of Consolidation C_v	Coefficient of Volume Compressibility M_v (M^2/KV)
						X%	Y%	Z%	Average %	Liquid Limit %	Plastic Limit %	Plasticity Index %			
A1	3	42	24	31	55	29.01	28.67	29.09	28.92	46.00	28.92	17.08	2.60	32.56	1.67×10^{-3}
A2	4	50	29	17	46	28.00	28.67	28.36	28.34	45.00	28.34	16.66	2.62	30.68	1.19×10^{-3}
A3	6	41	21	32	53	27.82	26.83	26.51	27.05	46.00	27.05	18.95	2.72	32.56	1.45×10^{-3}
A4	5	48	24	23	47	24.29	25.12	24.42	24.61	44.00	24.61	19.39	2.62	30.68	1.08×10^{-3}
A5	6	49	24	21	45	22.66	23.13	23.53	23.11	37.00	23.11	13.89	2.68	29.39	1.53×10^{-3}
A6	6	48	24	22	46	28.19	27.78	28.42	28.13	42.00	28.13	13.87	2.70	30.68	1.53×10^{-3}
A7	8	52	15	25	40	22.95	22.31	22.73	22.66	38.00	22.66	15.34	2.66	29.39	1.51×10^{-3}
A8	14	41	20	25	45	21.05	20.69	21.56	21.10	38.00	21.10	16.70	2.62	32.56	1.48×10^{-3}
A9	6	48	24	22	46	23.77	25.00	24.82	24.53	36.00	24.53	11.47	2.64	29.39	1.43×10^{-3}
A10	8	47	27	18	45	25.38	25.70	24.98	25.35	35.00	25.53	9.47	2.70	30.68	1.15×10^{-3}
B1	4	49	22	25	47	23.36	23.16	21.17	22.56	44.00	22.56	21.4	2.65	30.68	1.43×10^{-3}
B2	2	57	26	15	41	25.33	25.58	24.54	25.15	42.00	25.15	16.85	2.69	32.56	1.71×10^{-3}
B3	4	51	25	20	45	21.43	21.01	20.57	21.00	42.00	21.00	21.00	2.65	32.56	1.71×10^{-3}
B4	7	51	20	22	42	26.06	25.77	26.00	25.94	44.00	25.94	18.06	2.70	30.68	1.77×10^{-3}
B5	10	57	17	16	33	19.57	19.72	20.14	19.81	34.00	19.81	14.19	2.53	31.53	1.76×10^{-3}
B6	10	50	23	17	40	21.21	20.86	21.33	21.13	36.00	21.13	14.87	2.48	32.56	1.52×10^{-3}
B7	3	60	22	15	37	23.57	22.48	22.96	23.00	42.00	23.00	19.00	2.50	30.68	1.81×10^{-3}
B8	2	62	23	13	36	20.00	20.53	20.00	20.18	38.00	20.18	17.82	2.52	30.68	1.94×10^{-3}
B9	3	67	16	14	30	23.84	23.78	24.36	23.99	42.00	23.99	18.01	2.64	32.56	1.84×10^{-3}
B10	8	57	16	19	35	27.14	26.71	26.67	26.84	47.00	26.84	20.16	2.70	30.68	1.81×10^{-3}

materials (Table 1).

Coefficient of Volume Compressibility M_v

The values range from 1.08 x 10 $^{-3}$m^2/KN and 1.67 x 10^{-3}m^2/KN for soil samples collected from the study area A, with an average value of 1.42 x 10^{-3}m^2/KN while those in the study area B range between 1.43 x 10 and 1.94 x 10^{-3}m^2/KN with an average value of 1.74 x 10^{-3}m^2/KN (Table 1). Soil samples derived from granite in the study area B revealed higher average co-efficient of compressibility than those of quartzschist derived soil of study area A. The moderate compressibility values make those samples suitable for construction purposes.

Parent Rocks Influence on Plasticity and Compressibility Characteristics

This was determined by considering the mineralogy and wreathing processes of quartzschist and granite. High percentage feldspartic minerals (plagioclase) and micaceous mineral (biotite and muscovite) coupled with the presence of foliations in the rocks resulted to low resistance in weathering. The soil obtained from the rock contains high amount of fines, and little amount of coarse fraction. The dominant clay mineral in the quartzschist derived soil at the study area A is kaolinite while in study area B for granite derived soil the dominant clay mineral is illite. The space within the three layered structure of illite is prone to penetration of water and result in high plasticity index.

CONCLUSION

From the various tests carried out both laboratory and geotechnical, it revealed that quartzschist and granite derived lateritic soils are generally well-graded reddish brown, sandy-silt-clay of medium plasticity and compressibility with some little contents of clay of inorganic origin and higher plasticity index. The dominant clay mineral in the quartzschist derived soil of study area A is kaolinite while illite dominates the granite derived soil of the study area B. However, soils in the study area B have higher values of co-efficient of consolidation, C_v and co-efficient volume of compressibility, M_v than those in quartzschist derived soil.

The study also showed that the most influenced parameter by the parent rock is the co-efficient of compressibility followed by amount of fines, plasticity index and specific gravity while the least influenced is the co-efficient of consolidation. From geological and engineering perspectives, quartzschist and granite derived soils are good construction materials and with little compaction, the soils are suitable materials for landfill sites.

REFERENCES

Adeyemi, G.O., Ojo, A.O., Omidiran, M.O. 1990. Strength of three southwestern Nigerian Lateritic Clay Deposits: *Nig. Jour. Tech. Res.,* 2: 33 – 38.

Adeyemi, G.O. 2002. Geotechnical Properties of lateritic soils developed over quartzschist in Ishara Area Southwestern Nigeria: *A Journal of Mining and Geology*, 38(1): 65–69.

Ashworth, R. 1966. Highway Engineering: Heinemann Education Book Ltd. London, Pp. 62–79.

Balogun, I.A. 1982. The physiochemical and geotechnical properties of lateritic soils from southwestern Nigeria: Proceedings of first National Conference, Nigeria geotechnical Association, Lagos. P. 42 – 59.

De-Graft Johnson, J.W.S. 1972. Laterite gravel evaluation of road construction: *Jour. Soil. Mech. Div., Amst. Soc. Civil Engineering,* 98: 1245 – 1265.

De-Graft Johnson, J.W.S., Bhatta, H.S., Hammond, A.A. 1969. Engineering Properties: Proceedings of the specialty session on Engineering properties of lateritic soils, 2: 13 – 44.

Gidigasu, M.D. 1972. Mode of formation and Geotechnical Characteristics of laterite materials of Ghana in relations to soil forming factors: *Eng. Geol.*, 6: 79 – 150.

Ola, S.A. 1974. The potentials of Lime Stabilization of Lateritic Soils: *Engr. Geol.,* 11: 305–317.

(Manuscript received: 22nd February, 2010; accepted: 27th July, 2010).