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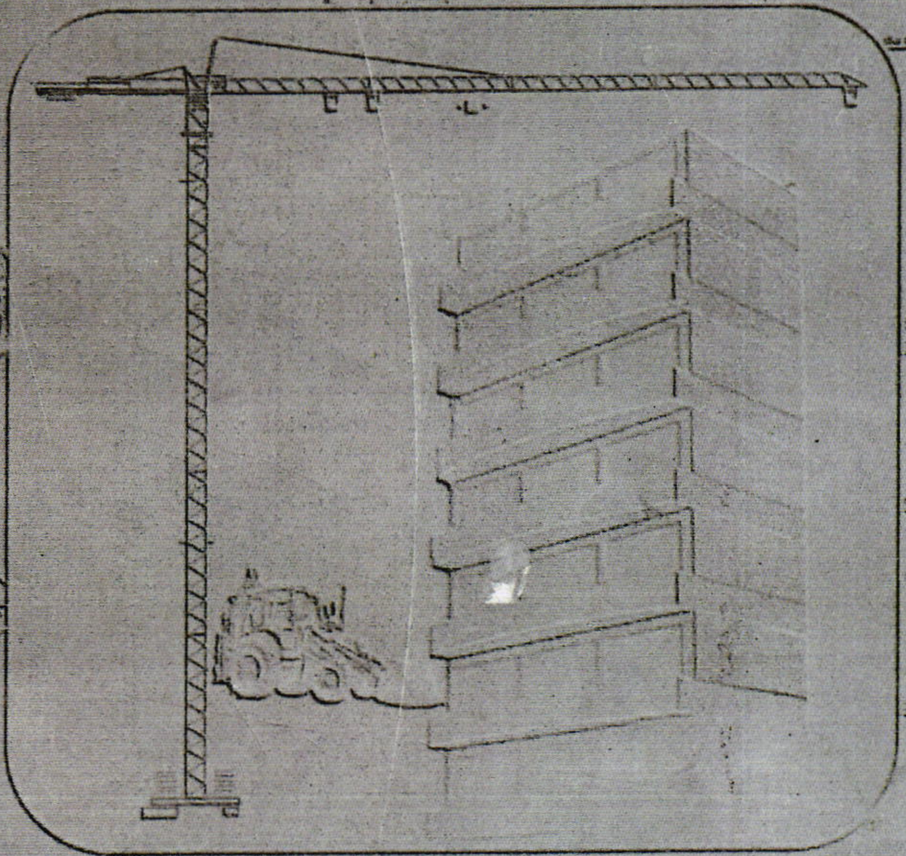

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INDEX AND COMPACTION PROPERTIES OF LATERITE DEPOSITS FOR ROAD CONSTRUCTION IN MINNA AREA, NIGERIA

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ABSTRACT: *Three laterite deposits located at Kampala, Kpakungu-Labiri and Gwada-Maraba areas of Minna, north-western Nigeria were assessed for their geotechnical characteristics with the aim of determining their suitability for road construction. Two samples were collected twenty-five meters apart from each location and analyzed. The soil was heterogeneous. The liquid limit varied from 32% to 46%, plastic limit ranges from 22.8% to 29.6% while the plasticity index was of the order of 6.9% to 16.4%. The shrinkage potential was generally low. The California Bearing Ratio (C.B.R) had a general rating of poor to excellent. The maximum dry density varied from 1.88g/cm^3 to 2.145 g/cm^3 while the optimum moisture content was of the order of 12% to 16%. The X-ray Diffraction (XRD) results indicated the presence of illite, kaolinite, and montmorillonite in decreasing order of abundance.*
KEYWORDS Geotechnical Assessment, X-ray diffraction, laterite, road construction, sieve analysis, plasticity index, compaction, California Bearing Ratio.

INTRODUCTION

Laterite has been used for centuries as a construction material in building low income houses (local) but its most effective use has been in the area of road construction (Abalaka, 1998). It has found useful application as a sub-base material in the construction of highway pavement (David, 1993). The suitability of laterite for a particular use is determined based on its index and compaction properties for example particle size distribution, plasticity, compaction properties and not on visual inspection or apparent similarity to other soils. Where such relevant knowledge is not properly ascertained, construction problems may result. In order to avoid or reduce post construction difficulties of road, a thorough geotechnical investigation of the sub-grade and materials for filling base and sub-base of highway pavement is necessary in order to ensure its durability.

The presence of iron and aluminium oxides or hydroxides determines the colour of laterite soils. Colour variation ranges from dark red to light brown depending on the relative values of the metal oxides present in the deposit (David 1993). This variation in lateritic soil depends on the mode of soil formation, climate, geologic history, type of weathering and erosion and the extent of laterization. Laterization is the removal of silicon through hydrolysis and oxidation that results in the formation of laterites. Lateritic soil due to their structural strength can be very suitable for sub-grades, though care should be taken to provide drainage and avoid particle breakdown from over-compaction.

This work focuses on the assessment of the geotechnical characteristics of laterite deposits from three locations (Kampala, Kpakungu Labiri and Gwada Maraba) areas of Minna metropolis, northwestern Nigeria with a view to appraising their suitability for road construction.

DESCRIPTION OF STUDY AREA

Kampala lies between latitude (9^{0}40′55″N and 9^{0}41′33″N) longitude (6^{0}26′13″E and 6^{0}27′ 00″E) east of Maikunkele (fig. 1). Kampala is characterized by valleys and ridges. Kpakungu Labiri is situated between latitude (9^{0}35′50″N and 9^{0}36′ 00″N) longitude (6^{0}30′00″E and 6^{0}32′00″E) [fig. 1]. The laterite in Kpakungu Labiri occurs as a north–south trending ridge in the northern and western part. Gwada Maraba lies between latitude (9^{0}43′00″N and 9^{0}44′37″N) longitude (6^{0}48′30″E and 6^{0}48′53″E) along Minna– Gwada road with a relatively flat topography (fig. 1).

General Geology of the Area

The areas investigated are part of North–Western Basement complex of Nigeria (Truswell and Cope 1963; Ajibade 1976).

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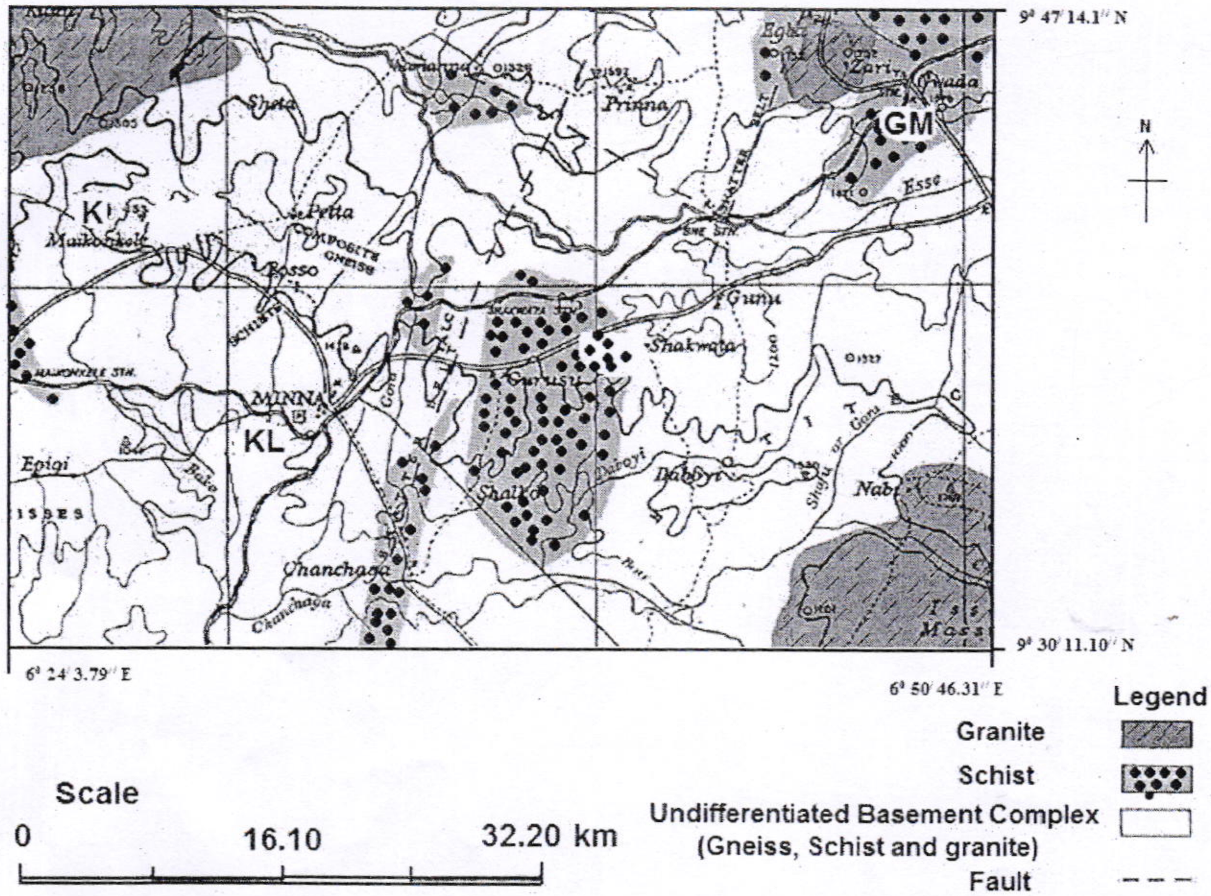


Fig. 1 Location map of the study areas inserted on a generalised geological map. (Modified after Truswell, & Cope, 1963).

K is Kampala, GM is Gwada Maraba and KL is Kpakungu Labiri.

The Nigerian basement complex is subdivided into three lithological suites; the migmatite/gneiss complex, low grade schist belt and the older (Pan African) granite. Field observations revealed that the older granites are the youngest of the three suites and they have been emplaced into both the migmatite/gneiss complex and the schist belts. The field descriptions of basement cover relationships in Minna region (fig. 2) are documented in Ajibade et al., 1987. Coarse grained granite/granodiorite occurs as ridges to flat low lying outcrop in Kampala. Medium to coarse grained granite/granodiorite with quartz and pegmatite veins characterize Kpakungu Labiri. Gneiss and granite occur in Gwada Maraba.

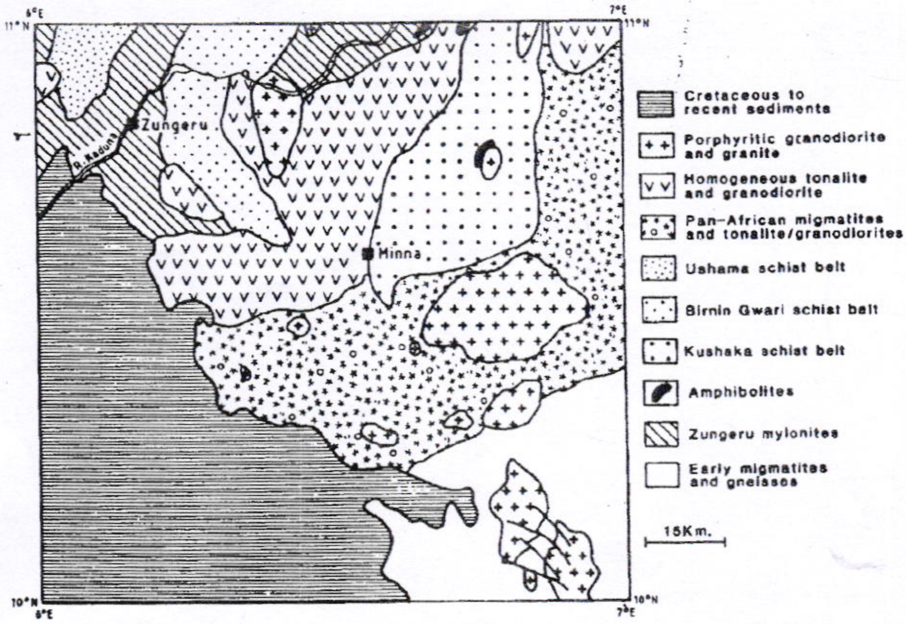


Fig. 2 Detailed geological map of Minna region (After Ajibade et al., 1987)

METHODOLOGY

Detailed geological mappings of three localities were undertaken with the aim of locating laterite deposits and establishing the host rocks. Two samples were collected at each location at twenty five metres apart. A total of six trial pits were excavated and soil samples were collected at depths of 0.1 to 0.5 meters according to British standard (BS) code of practice for site investigation (1981). Fifteen (15) kg each of the disturbed lateritic soil samples were collected from each trial pit. The samples collected were analyzed for relevant geotechnical properties in the laboratory according to British standard methods of test for soils for Civil Engineering purposes (British Standard Institution, BS 1990).

Sieve analysis, Atterberg limits (liquid and plastic limits), moisture content, compaction and California Bearing Ratio Tests were carried out on the soil samples. Selected lateritic soil samples were analyzed to determine the type of clay minerals present with x-ray diffraction (XRD) method.

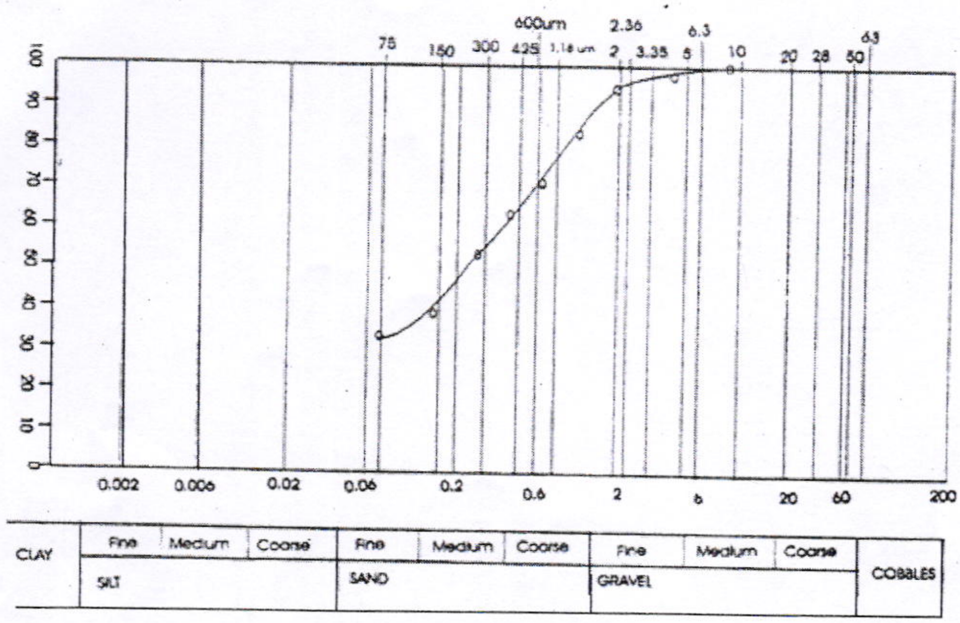
LABORATORY RESULTS

Sieve Analysis

The detail results of the sieve analysis are contained in Table 1. A typical particle size distribution curve is illustrated in Fig. 3.

Table 1. Particle Size Analysis Results

Sample No.	Location	Depth (m)	SIEVE ANALYSIS (% PASSING) [Sieve size in mm]									
			19.00	9.50	4.75	2.36	1.18	0.60	0.425	0.300	0.150	0.075
1.	Kampala	0.50	100.0	99.68	91.34	71.48	61.74	57.14	55.02	51.88	43.00	38.12
2.	Kampala	0.50	100.0	96.66	80.86	60.88	49.36	44.56	42.30	39.42	32.60	26.96
3.	Kpakungu Labiri	0.50	100.0	87.56	75.26	50.52	36.72	31.18	25.42	19.12	15.92	14.44
4.	Kpakungu Labiri	0.50	100.0	88.26	64.38	49.08	41.46	34.02	30.12	26.62	23.00	21.08
5.	Gwada Maraba	0.50	100.0	97.26	84.58	69.58	62.54	60.06	58.58	55.64	45.92	40.02
6.	Gwada Maraba	0.50	100.0	100.0	99.76	95.00	83.33	71.22	63.88	54.84	39.92	32.56



Particle Size (mm)

Fig. 3 Typical particle size distribution curve.

Table 2. Summary of Soil Classification

Sample No. / Location	Soil Particle Size (%)			Description	BSC	USC	AASHTO	General Rating As a Sub-base
	Silt + Clay	Sand	Gravel					
1 Kampala	40	25	35	Reddish brown, lateritic, sandy, gravelly, silty clay.	CLG	SC/ GM	A6	Fair To Poor
2 Kampala	27	13	60	Reddish brown, lateritic, sandy, silty clayey, gravel.	GPC	SC/ GM	A-2-6	Good To Excellent
3 Kpakungu Labiri	14	26	60	Reddish brown, lateritic, silty clayey, sandy, gravel.	GPC	SC/ GM	A-2-6	Good To Excellent
4 Kpakungu Labiri	28	22	50	Reddish brown, lateritic, sandy, silty clayey, gravel.	GPC	SC/ GM	A-2-4	Good To Excellent
5 Gwada Maraba	40	25	35	Reddish brown, lateritic, sandy, gravelly, silty clay.	CLG	SC/ GM	A-7-6	Fair To Poor
6 Gwada Maraba	35	55	10	Reddish brown, lateritic, silty, clayey, gravelly, sandy.	GCL	SC/ GM	A-2-4	Good To Excellent

The British classification (BSC), Unified soil (USC) and AASHTO (American Association of State High way and Transportation Officials) classification of the soil samples are summarised in table 3. The laterite samples collected from Kampala and Gwada Maraba are heterogeneous while those retrieved from Kpakungu are homogeneous.

Atterberg Limits

The summary of the Atterberg limits is presented in table 3. Samples numbers 1, 2 and 4 are of low plasticity while samples 3, 5 and 6 are of intermediate plasticity. Shrinkage potential of the soil samples are generally low and the description is contained in table 3.

Compaction Test

The results of the compaction test are summarized in table 3. Compaction test is normally undertaken in order to obtain data to control the degree of compaction satisfactory at reasonable cost. Laboratory compaction tests provide the basis for control procedure used on site. Compaction on site is usually effected by mechanical means such as rolling, ramming or vibrating on soil placed as engineering fill in order to compact it to a dense state so as to obtain satisfactory engineering properties. Compaction improves the soil by increasing its stability and CBR (California Bearing Ratio) values and by reducing its compressibility and frost susceptibility (Ele International, 2009).

A typical graph of dry density against moisture content is presented in Fig. 2. The importance of the moisture–density relationship is to aid in checking the moisture content of soils being worked in order to obtain maximum compaction. The determined maximum dry density in the laboratory provides a standard to which the compaction in the field has to comply (Ministry of works and Transport, Osogbo, 1999; Matanal, 1990 and 1991).

Table 3 Summary of Laboratory Results

		ATTERBERG LIMIT (%)				C. B. R.		COMPACTION	
Sample No./ Location	Depth (m)	LL	PL	PI	SP	Soaked %	Unsoaked %	MDD (g cm^3)	OMC (%)
1. Kampala	0.50	34.0	23.40	10.60	Low	Not tested	55.00	2.04	12.0
2. Kampala	0.50	34.0	22.80	11.20	Low	Not tested	37.80	2.14	12.0
	MEAN	34.0	23.10	10.90			46.40	2.09	12.0
3. Kpakungu Labiri	0.50	37.0	24.80	12.20	Low	37.40	Not tested	2.03	12.0
4. Kpakungu Labiri	0.50	32.0	25.10	6.90	Low	35.70	Not tested	1.88	12.0
	MEAN	34.50	24.95	9.55		36.55		1.96	12.0
5. Gwada Maraba	0.50	46.0	29.60	16.40	Low	Not tested	59.70	1.89	16.0
6. Gwada Maraba	0.50	35.0	27.16	7.84	Low	Not tested	38.40	2.04	14.0
	MEAN	40.50	28.38	12.20			49.05	1.97	15.0

LL=Liquid Limit, PL=Plastic Limit, PI=Plasticity Index, SP=Shrinkage Potential,
C. B. R. =California Bearing Ratio, MDD=Maximum Dry Density,
OMC=Optimum Moisture Content.

California Bearing Ratio (C. B. R.) Test

The California Bearing Ratio test results are presented in Table 4. The California Bearing Ratio (CBR) test is a simple strength test that compares the bearing capacity of a material with that of a well-graded crushed stone (thus, a high quality crushed stone material should have a CBR of 100%). It is primarily intended for, but not limited to, evaluating the strength of cohesive materials having maximum particle sizes less than 19 mm

(AASHTO, 2000). It was developed by the California Division of Highways around 1930 and was subsequently adopted by numerous states, counties, U.S. federal agencies and internationally.

The penetration–load data for unsoaked and soaked C.B.R. tests provide necessary information used in classifying the soil and in determining their performance and suitability as sub-grade or base course in highway and airfields construction. In addition, soaked C.B.R. test provides information on expected soil expansion beneath the pavement when the soil becomes saturated and gives an indication of strength loss from field saturation (American Association of State Highway of Officials, 2000). Fig. 4 illustrates the California Bearing Ratio curve. The summary of the soil classification is presented in table 3.

Table 4. California Bearing Ratio Results and Its Applications.

				C. B. R.			
Sample No.	Location	Trial Pit	Depth (m)	Soaked %	Unsoaked %	General Rating	Uses
1.	Kampala	1	0.50	Not Tested	55.00	Excellent	
2.	Kampala	2	0.50	Not Tested	37.80	Good	Sub-base
					Mean= 46.40	Good to Excellent	
3.	Kpakungu Labiri	3	0.50	37.40	Non	Good	Sub-base
4.	Kpakungu Labiri	4	0.50	35.70	Non	Good	Sub-base
				Mean= 36.55		Good	
5.	Gwada Maraba	5	0.50	Not Tested	59.70	Excellent	Base
6.	Gwada Maraba	6	0.50	Not Tested	38.40	Good	Sub-base
					Mean= 49.05	Good to Excellent	

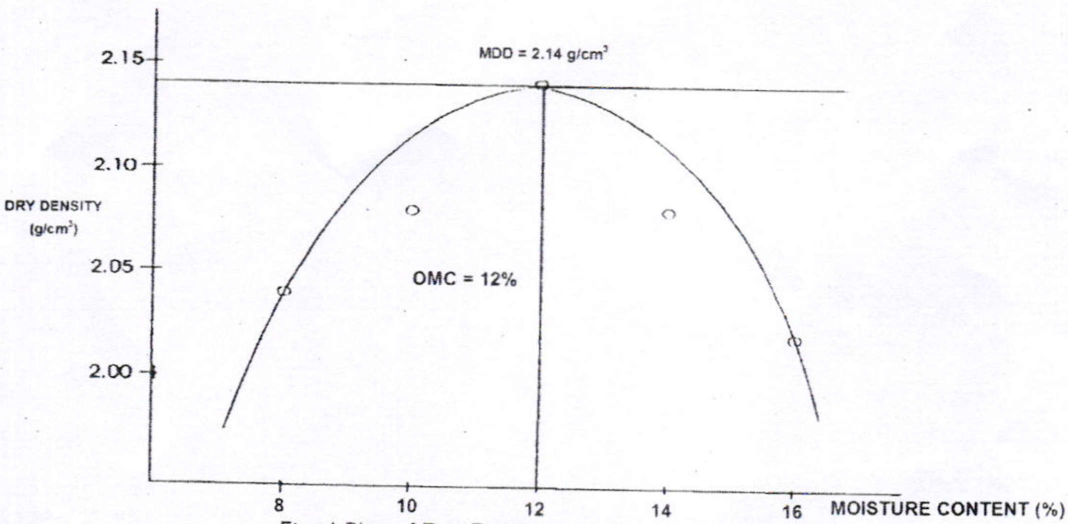


Fig. 4 Plot of Dry Density against Moisture content.

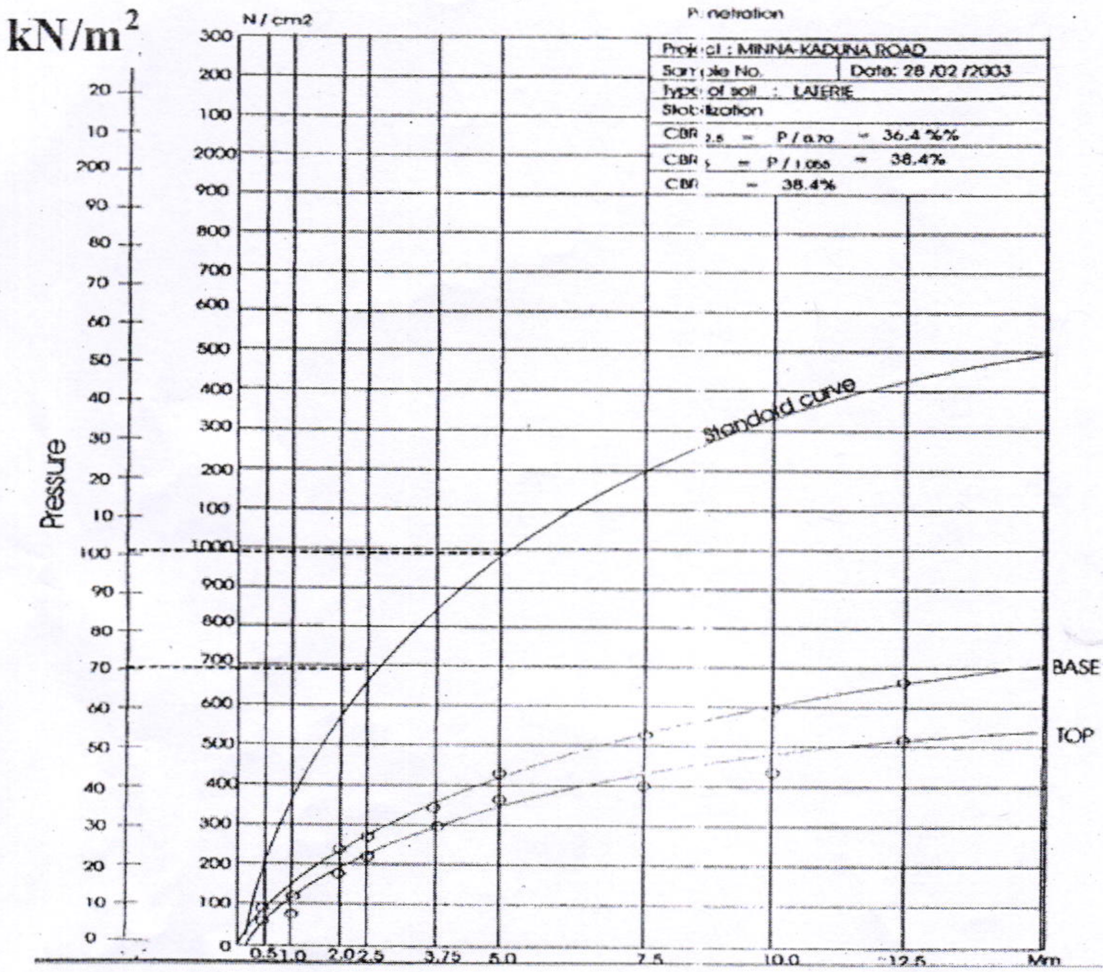


Fig. 5 California Bearing Ratio Curve

X-ray Diffraction Test

About 2kg of each lateritic soil samples from Kampala and Gwada Maraba were mixed together for x-ray diffraction analysis to establish the types of clay minerals. The soil samples were selected based on plasticity index of 12% and above and intermediate plasticity of sample number 3, 5 and 6 collected from Kpakungu and Gwada Maraba.

The results indicate that illite, kaolinite, montmorillonite were identified in order of abundance. Illite is derived principally from the weathering of muscovite and biotite contained in granitic gneiss and granite. Montmorillonite is active and swells in the presence of water and its general formular $\{Al_4[Si_6Al_2O_{20}](OH_4)\}^{2-}$. nH_2O, where nH_2O is the interlayer of absorbed water (Gribble, 1991). The weathering of montmorillonite often produces kaolinite and in areas where weathering has progressed, both minerals are usually present (Bowles, 1984). In summary, kaolinite is the least active clay mineral; illite is of intermediate activity and montmorillonite the most active.

CONCLUSION

The results of the classification tests (sieve analysis, liquid and plastic limits), California Bearing Ratio (C.B.R.) and compaction tests indicate that: (1) the lateritic soil from Kampala is suitable for the construction sub-base of roads. (2) Kpakungu Labiri lateritic soil can be used for making sub-base layers of road. However, sample number 3 collected at Kpakungu has plasticity index of 12%. (3) The C.B.R. test undertaken on samples collected from Gwada Maraba indicates that the soil can be used for sub-base which is further confirmed by the classification tests. However, sample number 5 has a plasticity index of 16.4%, though with a low shrinkage potential.

Laterite with medium to high shrinkage potential and intermediate plasticity is undesirable in road construction because of their tendency to swell and shrink as a result of increase and decrease in moisture content respectively. This is due to the presence of certain types of clay minerals like montmorillonite and illite obtained from XRD results. The resultant effect is the development of cracks and pot holes which will eventually lead to road failure. It should therefore not be used and laterite with lower plasticity index should be utilized.

Evaluation of the geotechnical properties of the laterite deposits in Kampala, Kpakungu Labiri and Gwada Maraba has revealed their suitability and inappropriateness for road construction purposes. Diligent application of these data will minimize highway failure, prevent road accident and ensure its durability.

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