Journal of Geology and Mining Research Vol. 3(8), pp. 193-200, August 2011
Available online http://www.academicjournals.org/JGMR
ISSN 2006-9766 ©2011 Academic Journals

Full Length Research Paper

Engineering geophysical investigation of a flood zone: A case study of Alaba Layout, Akure, Southwestern Nigeria

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Accepted 30 May, 2011

Geotechnical and geophysical investigation involving electrical resistivity survey and laboratory test of soil samples were carried out at Alaba Layout, close to the Federal University of Technology, Akure temporary site. Sixteen vertical electrical soundings were conducted within the study area and laboratory tests conducted on soil samples obtained at three different locations in the area. Three major lithologic units were delineated from the electrical resistivity survey results comprising topsoil characterized by mudstone topsoil, plastic clay/weathered basement and the fresh bedrock. Resistivity values for the various units range from 12 to 210 Ωm, 18 to 381 Ωm and 8084 to 47009 Ωm respectively. Depth to the basement estimated for the sixteen sounding locations vary between 4.1 m to 25.2 m. The geotechnical tests carried out on the soil samples indicated that the soils comprising the overburden materials in the study area graded from plastic organic clayey to intermediate plastic clayey soils. These soils have strong affinity for water absorption and swelling which will increase the activity of the clay minerals in the overburden materials. In addition, the overburden materials exhibit strong shrinkage ability thereby posing serious compaction problems to any engineering works, such erection of buildings, road construction and other forms of civil engineering works.

Key words: Engineering geophysics, flood, Atterberg limits, linear shrinkage.

INTRODUCTION

In recent times land expanses around the Federal University of Technology, Akure temporary site have been opened to rapid development. The study area and several adjoining communities which were rural settlements in the past, extending several kilometers around the southern gate of the campus, comprising such settlements like the old Aba Oyo and Iloyin Villages have been opened up for urban development. These villages have been demarcated into several layouts such as Alaba, Apatapiti, Abidakun, Akinwumi, Omotayo layouts, among others. These communities have witnessed drastic phases of urbanization and industrialization with little or no consideration for proper land developmental planning.

Despite this rapid developmental growth, attention has not been properly paid to the influence of the subsurface soil and landscape of the various agents of denudation and geomorphologic factors. The impact of such factors like rainfall, topography and soil characteristics manifest in forms of erosion, flood and road failures.

This work aims at providing geophysical and engineering information of the subsurface geology within Alaba Layout, and pointing out the problems that may be associated with foundation failure if adequate cognizance of the properties of soil of such newly developed area is not taken into account.

GEOLOGICAL SETTING

The study area falls within Akure Northwest and lies between latitude 7° 17.5’ N to 7° 17.9’ N and longitude 5° 9.1’ E and 5° 9.5’ E (Figure 1). Geomorphologicaly, the study area falls within unevenly topographic landscapes characterized by features like spurs, saddles, valleys, and river channels among several landforms. The area

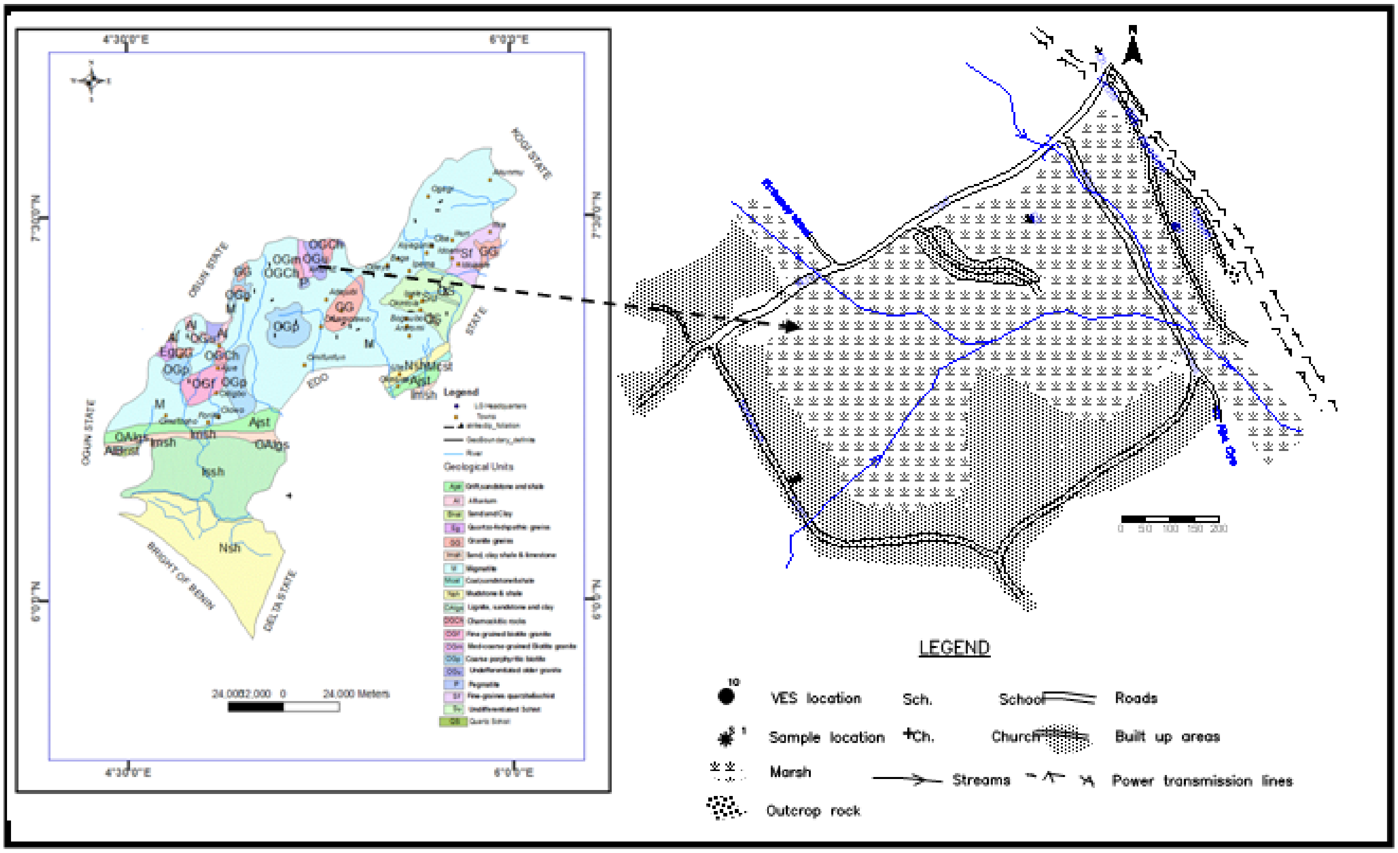

Figure 1. Geological map of Ondo State showing the location of the study area (after GSNA, 2006) and site description map of the study area.

lies within a flood zone that has been found to form the heart or possibly the middle to lower course of an old river channel. The same channel extends through some areas in the northwestern part of Akure. The river was discovered to have changed its course in the time past due to cutting-in into the old river channel by a later stream flowing in the west-east direction in the northwestern part of Akure. This has left a wide gap close to the Agape Christian Possibility Ground along Ilesa Road. The old river that has changed its course due to the cutting in of the later is believed to be an occasionally rejuvenated tributary to the troublesome Ala River that permeates through the central part of Akure. The flood plain formed by this wide gap along the old river channel is usually used for cultivation of the lowland rise.

Geologically, the region forms part of the basement complex of the southwestern part of Nigeria (Rahaman, 1998; Jones and Hockey, 1964; Cooray, 1970). Major rock types around the area are Chanockite, Migmatite gneiss, Quartzite and Biotite gneiss. These Precambrian rocks have however, been subjected to tectonic activities and disturbed in various ways resulting in fracturing, jointing, cracking among others (Rahaman, 1988; Oyawoye, 1970).

METHODOLOGY

Electrical resistivity survey

The field measurement of the electrical resistivity data involving vertical electrical soundings were conducted in the third months of the year 2002 just before the raining season. Sixteen vertical electrical soundings were conducted using a RD-50 resistivity meter using Wenner array with electrode separations (AB/3) varied between 1 and 96 m. The field data obtained was presented as spatial distribution of the resistivity values at different electrode spacings of 1, 4, 8, 32 and 64 m (Figure 2). Sounding curves obtained from the field data were subjected to manual interpretation using partial curve matching technique. Modelled curves calculated from the curve matching were then refined through automatic computer iteration using a resistivity inversion programme, RESIST version 1.0, based on the Gosh (1971) linear filtering theory. Results of the sounding curve interpretation are shown Figure 3 and Table 1.

Soil classification and geotechnical tests

The geotechnical analyses were carried out on soil samples collected at three different locations and subjected to visual and laboratory tests in order to determine their physical and geotechnical properties. The laboratory analysis of the involved soil particle size distribution and Atterberg limits tests using the British

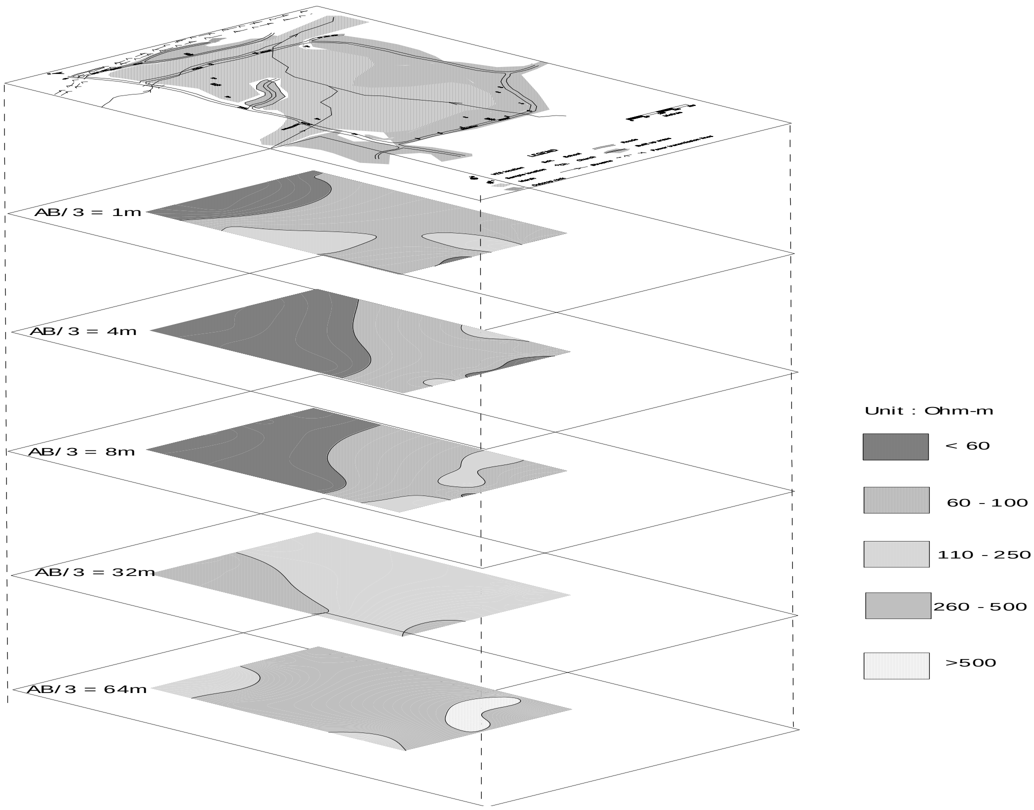

Figure 2. Spatial distribution of apparent resistivity at AB/3 = 1, 4, 8, 32 and 64 m.

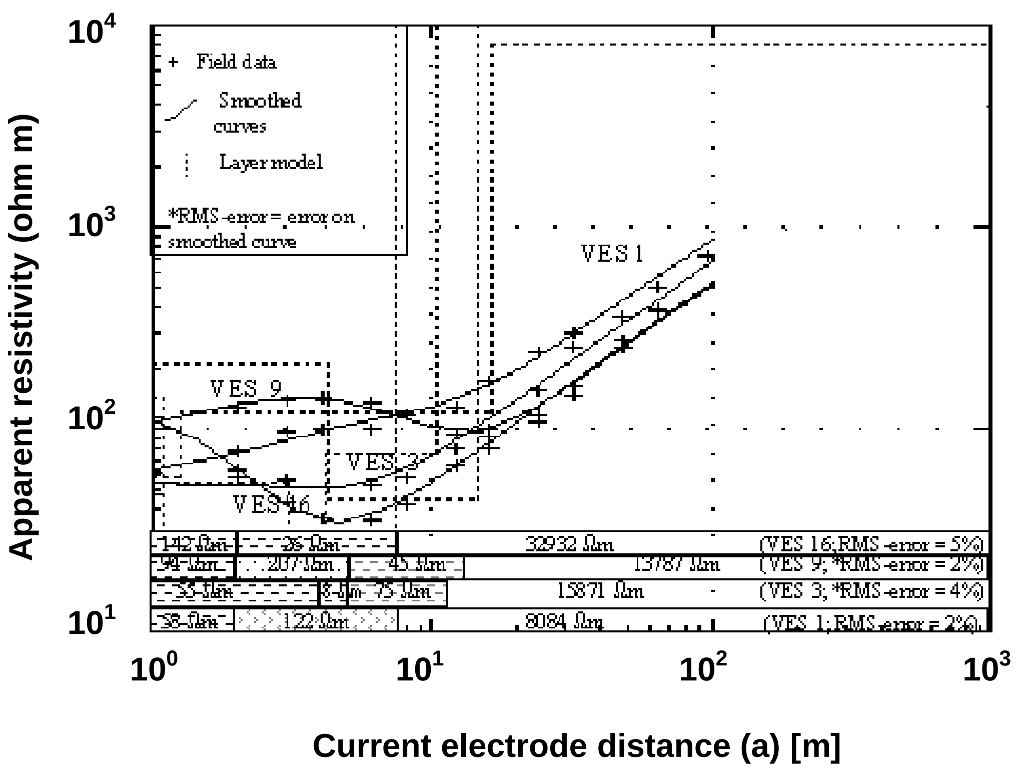

Figure 3. Typical iterated sounding curves.

Table 1. Summary of the qualitative interpretation and geologic inference from the sounding curves.

Curve type	Estimated layer parameters and inferred lithologic units							
		Topsoil	Intermediate/ weathered layer	Bedrock		% Distribution	Depth to Bedrock (m)	Aquifer type
A	Range of thickness	1.0-2.4	4.5-7.9	α		19	6.9-9.9	Unconfined sandy clay/ clayey sand aquifer.
	Range of resistivity (Ωm)	12-58	27-177	8084-38438				
	Inferred lithology	Organic/ clayey soil	Clayey/ sandy clay	Fresh bedrock				
H	Range of thickness	0.8-1.9	5.6-9.9	α		31	6.4-11.0	Unconfined clayey sand/ highly decomposed basement aquifer.
	Range of resistivity (Ωm)	15-210	11-44	21024-47009				
	Inferred lithology	Organic/ clayey soil	Plastic clay/ mud stone	Fresh bedrock				
		Topsoil	Intermediate layer	Weathered layer	Bedrock			
KH	Range of thickness	0.7-4.2	1.4-13.2	2.0-14.3	α	44	9.3-25.2	Unconfined gravelly sand/ Weathered basement aquifer.
	Range of resistivity (Ωm)	67-127	15-212	26-381	9989-13787			
	Inferred lithology	Clay/ sandy clay	Organic clay/ clayey sand	Clayey sand/ gravelly sand	Fresh bedrock			
HA	Thickness	3.1	1.0	6.3	α	6	10	Unconfined gravelly sand aquifer.
	resistivity (Ωm)	55	18	75	15871			
	Inferred lithology	Clay	Organic/ plastic clay	Clay	Fresh bedrock			

systems (BS) and American society for testing and materials (1980) standard for soil classification. Sieve and sedimentation analyses were carried on 250 g of each sample. Particle size distribution evaluation of the representative sample of these soils was conducted with a set of different sieve openings based on the BS 5930 (1981). Particle size distribution chart was later employed to estimate the average percentage of sand and gravel in the soil samples (Table 3). Soil classification was based on the unified BS classification standard (BS 5930: 1981) of the soil samples based on the Atterberg limit values for the fraction passing the 63 mm BM sieve.

DISCUSSION OF RESULTS

Spatial distribution of apparent resistivity

Variations in apparent resistivity with depth in the study area were modeled from the plots of apparent resistivity versus electrode separation (AB/3), at different levels (Figure 2). The trend observed shows a gradual increase in the apparent resistivity with depth (increase in electrode separation) as well as increase in resistivity towards the southeastern part of the area. At shallow level (AB/ = 1 m), apparent resistivity ranging between 10 to 140 Ωm characterize topsoil grading from plastic clay (< 60 Ωm) to less competent clayey material (60 to 100 Ωm) to clayey sand (110 to 250 Ωm). At intermediate levels (AB/3 = 4 and 8 m), a localized low resistivity value less than 100 Ωm diagnostic of plastic clay (or mud stone) was inferred for the central part of the study area. It was observed that ittrend in the northwestern direction. At more deeper levels, that is, (AB/3 = 32 and 64 m), a gradual increase in the resistivity value from 80 to 290 Ωm for AB/3 = 32 m, and 120 to 560 Ωm for AB/ = 64 m was generally observed. It was thus deduced that the superficial materials overlying the bedrock in the area is characterized by low resistivity values depicting highly saturated and incompetent overburdens typical of alluvium deposit.

Characteristic geoelectric parameters and their geologic inference

Table 1 shows the qualitative interpretation of the vertical electrical soundings and inferred characteristics of the underlying lithologic units in the area. Typical computer aided interpreted sounding curves obtained for the areas are presented in Figure 3.

As shown in the Table 1, three to four lithologic units were delineated. These comprises of the topsoil, clayey sand and/or sandy clay, weathered aquifer and the fresh bedrock. The KH-curve type depicting a four-layer geoelectric profile is the dominant curve type for all the sounding curves in the area. The first unit of the geoelectric profile is characterized by topsoil varying in thickness between 0.7 and 4.2 m and layer resistivity ranging between 67 and 127 Ωm diagnostic of clayey to sandy clay soil. The second layer has thickness that varies from 1.4 to 13.2 m and resistivity values varying from 15 and 212 Ωm characteristic of organic clay to clayey sand. The third unit and presumed weathered layer has thickness varying from 2.0 to 14.3 m with resistivity value ranging between 26 and 381 Ωm indicating highly decomposed to gravelly material. Underlying bedrock resistivity values varied between 9989 and 13787 Ωm.

The H-type curve is the next dominant curve type, which comprises the topsoil with thickness varying from 0.8 to 1.9 m and layer resistivity value that varies between 15 and 210 Ωm characteristic of organic to clayey soil. The topsoil is followed by highly decomposed or weathered unit presumed to be made up of plastic clay or mud stone having resistivity value that varies from 11 to 44 Ωm, with layer thickness of 5.6 to 9.9 m. Underlying fresh bedrock has resistivity values that ranges between 21024 and 47009 Ωm.

The A-type curve follows the H-type curve in distribution, indicating lithologic sequence characterized by topsoil with thickness between 1.0 and 2.4 m. This layer has resistivity value varying from 12 to 58 Ωm characteristic of organic to clayey soil. The intermediate weathered unit has resistivity values ranging between 27 and 177 Ωm characteristic of clayey to sandy clay material with thickness ranging between 4.5 and 7.9 m. The underlying bedrock is characterized by resistivity value that ranges between 8084 to 38438 Ωm. The only HA-type curve was obtained at VES 3 along the southern part of the study area along Stateline Street. It comprises of topsoil with thickness of 3.1 m and layer resistivity of 55 Ωm characteristic of clayey soil. The second thin layer has thickness of 1.0 m and resistivity value of 18 Ωm characteristic of organic clay. The weathered unit has thickness of 6.3 m with resistivity value of 75 Ωm diagnostic of highly decomposed or clayey material. However, the underlying fresh bedrock has resistivity value of 15871 Ωm.

Engineering properties

The amount and type of clay minerals in soil being considered for construction materials influence their suitability for such earthworks. The affinity, which a soil has for water, depends on the predominant clay minerals and the most characteristic of a clay soil is its plasticity (Wilson, 1969; Berry and Reid, 1987). In addition, the errosivity and erodibilty of soil materials also depend on such factors as water transportation, speed and other factors of denudation. The knowledge of the influence of these factors and understanding of the soil characteristics for the sub-base and sub-grade materials prior to any engineering works may assist in the erection of buildings, road construction and other forms of civil engineering works (Simon et al, 1973).

Atterberg limits

The consistencies of natural clay vary significantly with water content. The water content at which consistency changes from one state to another are found to differ from one clay type to another, depending upon the amount and type of clay minerals present within it. The influence of amount and type of clay minerals in construction materials on their geotechnical properties has been emphasized by various authors, notable amongst them are Simon et al. (1973); Asere et al. (1998); Alabo and Johnnary (1997); Tse and Akpokodje (2002) and Adeyemi (2002).

The results of the consistency limit tests on the soil samples collected within the study area are shown in Table 2 and the plasticity chart classification are shown in Figure 4. The liquid limit (W_L) for the soil samples range between 35 and 75%, while their plasticity index (PI) vary from 17 to 46%. The first sample S_1 is classified as very high plastic clayey soil with PI of 46% and W_L 75%. Sample S_2 is classified as intermediate clayey soil with PI of 20% and W_L of 37%. The third sample S_3, however, can be classified as low plastic clayey soil having PI of 17% and W_L 35%.

These three samples, exhibit a great tendency for water absorption and swelling which will increase the activity of the clay minerals in the soil samples (Berry and

Table 2. Soil classification (Atterberg limits) and description.

Sample	Depth (m)	Physical description	Linear shrinkage, W_S (%)	Plastic limit, W_P (%)	Liquid limit, W_L (%)	Plasticity index, W_L-W_P (%)
S_1	2.0	Dark grayish organic soil	14.3	29	75	46
S_2	2.0	Grayish to brown clayey soil	11.4	17	37	20
S_3	1.5	Light brown Clayey soil	6.9	18	35	17

Table 3. Particle size grading for the soil samples.

BS sieve	Percentage passing (%)		
	Sample 1	Sample 2	Sample 3
3.35 mm	99.70	99.73	98.63
2.36 mm	99.40	99.60	97.40
850 µm	97.03	98.53	93.40
425 µm	91.46	95.03	88.20
300 µm	88.53	94.56	88.14
150 µm	77.53	81.96	74.57
75 µm	77.03	81.69	74.34
63 µm	ND*	74.66	ND

ND* = Not done

Reid, 1987; Gidigasu, 1980). Although S_3 sample exhibits fare shrinkage ability, both samples S_1 and S_2 however, have high shrinkage ability. In addition, both S_2 and S_3 would have low to medium swelling potential (Adeyemi, 2002). The values of PI of these soils are less than upper limit of 25% recommended for sub-base and sub-grade materials in tropical Africa by the French for example Mmedina (1963) in Adeyemi (2002). The low plasticity could be attributed to high illite in the soil samples. However, sample S_1 with high values of PI (46%) and W_L (75%) was found unsuitable as sub-base or sub-grade material for foundation. This supports the observation in the central low land portion of the study area where some signs of distress is noticed on some buildings and road failure observed along the FUTA road across this section.

Linear shrinkage

Table 3 shows that the linear shrinkage values of the soil samples really agree with the PI values. The linear shrinkage values of 14.3 and 11.4% obtained for samples S_1 and S_2 indicate that the samples will likely pose a significant field compaction problem, for example, Gidigasu (1973) in Adeyemi (2002). However, the shrinkage limit value (6.9%) for sample S_3 is below the maximum value 8% suggested by Madedor (1983) for sub-base materials, an indication that the soil would not pose a serious compaction problem. However, the low shrinkage limit may aggravate erosion in this area because of non-cohesion of the plastic clay material.

Grain size distribution

The grading curves (Figure 5) for the soil samples clearly show that the proportion of fine sized particles (Silt and clay) of diameter less than 0.075 mm is very high with small percentage of coarse to medium grained particles. Both Figure 5 and Table 3 indicated that over 70% of the soil samples passed the number 200 (75 µm) sieve based on the British soil classification system. Since more than 35% of the materials of these soils are finer than the 0.06 mm, the soil samples are classified as follows:

Sample S_1 (W_L = 76%) very high plastic organic clay material,
Sample S_2 (W_L =37%) intermediate plastic clay material,
Sample S_3 (W_L = 35%) low plastic clay material.

Conclusions

The results of the geophysical and geotechnical studies at the Alaba Layout in Akure metropolis reflects a paradigm of indiscriminate occupation or erection of buildings within flood zones with little or no consideration for proper land developmental planning. Most of these areas are usually demarcated as public utility areas,

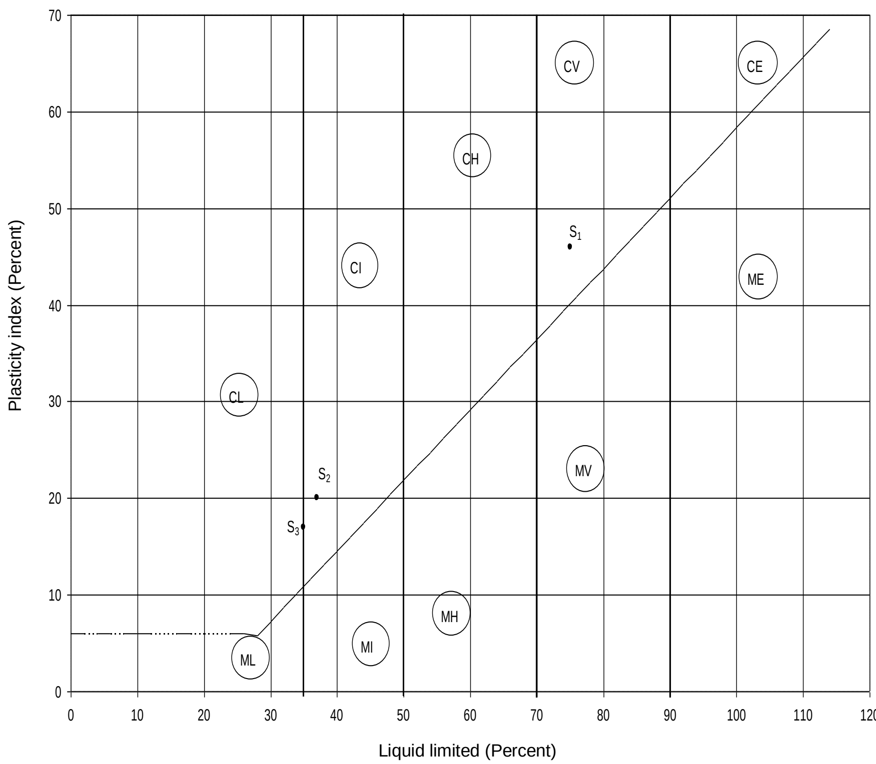

Figure 4. Plasticity chart for the soil samples (British Classification System; from BS 5930: 1981).

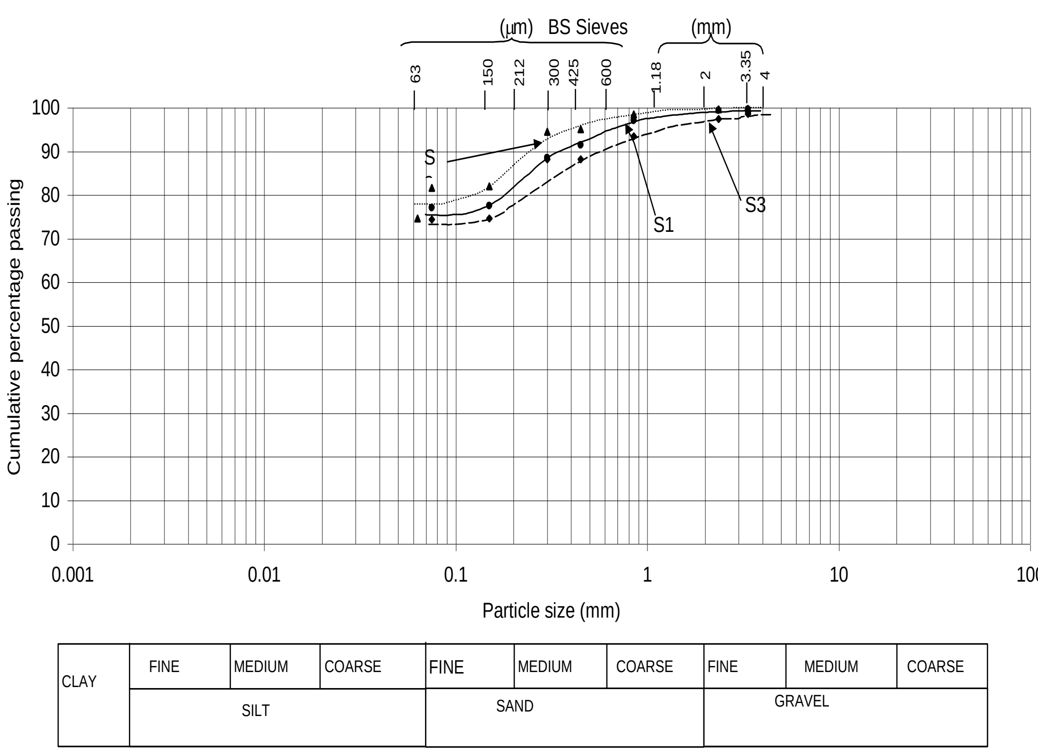

Figure 5. Grading curves of the soil samples.

which are government reservation areas. In addition, several of these wrongly harnessed land resources would have been used for agricultural purposes.

The geophysical survey revealed a subsurface lithologic sequences that grades from clayey (likely organic) topsoil into the less competent clayey to clayey sand intermediate layer followed by a low resistive highly decomposed or weathered zone, which are likely to pose foundational problems. Underlying this layer is the fresh bedrock characterized by fairly low resistivity values in some areas. This is an indication of possible development of secondary porosity within the bedrock characterized by macro-anisotropy (generally fracture anisotropy) and hydraulic conductivity. Overburden materials are mostly thin with exceptions at areas with high surface elevation.

The engineering laboratory tests carried out on the soil samples indicated that the soils in the study area graded from plastic organic clayey to intermediate plastic clayey to low clayey soil at the adjoining Lydia Street. The soils show great tendency for water absorption and swelling due to high percentage of clay minerals, which will lead to significant increase in clay activities.

The PI values of the soils in the area were found to be above the prescribed limits for the sub-base and sub-grade materials for tropical Africa. Estimated linear shrinkage values also support the likelihood of the soils in the area posing considerable compaction problems and possibility of inducing erosion because of the non-cohesion of the plastic clay material.

REFERENCES

Adeyemi GO (2002). Geotechnical properties of lateritic soil developed over quartz schist in Ishara area southwestern Nigeria. J. Min. Geol., 38(1): 65-69.

Alabo EH, Johnnary T (1997): 'Geotechnical investigations of Deltaic bridge site: A case study in the eastern Niger Delta', Geophysical prospecting, 33(1). 25-34.

American Society for Testing and Materials (1980). Annual Book of ASTM standards, Part 19, Natural Building Stones: Soil and Rock, ASTM, Philadelphia, Pennsylvania.

Asere AA, Egwurube JA, Salawu OBE, Tokan A (1998). The effect of major road wash-away on highway construction: A case study from Northern Nigeria. NJTE, 15(1): 26-40.

Berry PL, Reid D (1987). An introduction to soil mechanics. McGraw-Hill Book Co., London: pp.1-317.

BS 5930 (1981). 'Code of practice for site investigations', British Standard Institution, London. In Berry and Reid (Ed): 'An introduction to soil mechanics'. McGraw-Hill Book Co London (1987), pp.1-317.

Cooray PG (1970). Note on the Charnockites of the Akure-Ado Ekiti area, western Nigeria. In Dessauvagie and Whiteman (Ed). Proceedings of the conference on African Geology, Dept. of Geology, U.I., (Dec 1970): pp. 45-53.

Gosh DP (1971): Inverse filter coefficient for the computation of apparent resistivity standard curves for horizontal stratified earth. Geophysical prospecting. 19: 761-775.

Gidigasu MD (1980): 'Geotechnical evaluation of residual gravel in pavement construction'. Eng. Geol., Amsterdam. 15:173-194.

Jones HA, Hockey RD (1964): 'The geology of part of South-western Nigeria'. Geol. Survey Bull. (31), Kaduna: pp. 1-101.

Madedor AO (1983): Pavement design guidelines and practice for different geological areas in Nigeria. In Adeyemi (Ed): 'Geotechnical properties of lateritic soil developed over quartz schist in Ishara area southwestern Nigeria'. J. Min. Geol., 38(1): 65-69.

Oyawoye MO (1970): The basement complex of Nigeria. In Dessauvagie and Whiteman (Ed). Proceedings of the conference on African Geology, Dept. of Geology, UI (Dec 1970); pp. 57-99.

Rahaman MA (1988). Recent advances in the study of the basement complex of Nigeria. In Precambrian Geology of Nigeria. Geol. Surv. Nig., 11s43.

Simon AB, Giesecke J, Bidlo G (1973). Use of lateritic soils for road construction in Northern Dahomey. Eng. Geol., Amsterdam. 7: 197-218.

Tse AC, Akpokodje EG (2002). Geotechnical evaluation of some sand deposits in parts of the eastern Niger Delta, Nigeria. J. Min. Geol., 38(2): 135-141.

Wilson EM (1969). Engineering geology, 4th Edition, Macmillan Press Ltd., London. pp. 1- 348.