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An Assessment of The Geotechnical Properties of The Subsoil of Parts of Federal University of Technology Minna, Gidan Kwano Campus, For Foundation Design and Construction.

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Abstract

The subsoil conditions of parts of Federal University of Technology, Minna permanent site (Gidan Kwano campus), northwestern Nigeria was investigated by excavating six trial pits from the existing ground level to between (1.00 to 1.5) meters. Twenty disturbed and undisturbed samples were collected and sent to Julius Berger Nigeria PLC laboratory, Minna and National Steel Raw Material Exploration Agency, Kaduna for relevant geotechnical analysis. Prior to the excavation, lithological and structural mapping was undertaken to reveal the presence of any geologic features that might affect the foundation of building and anticipated construction difficulties. The soil is heterogeneous. The liquid limit ranges from 18.0% to 43.0%, the plastic limit varies from 13.8% to 28.0%. The plasticity index is of the order of 2.1% to 18.1%. The pH is neutral, sulphate (SO_4^{2-}) and chloride (Cl^-) contents are negligible. The soil cohesion (C) ranges from 130 KN/m^2 to 164 KN/m^2 while the angle of internal friction (ϕ) is 8^0. The coefficient of consolidation (C_v) varies from 1.47 m^2/yr to 2.57 m^2/yr. The coefficient of volume compressibility (M_v) ranges from 0.20m^2/MN to 1.15 m^2/MN and the compression index (Ce) is of the order of 0.32 to 0.38. Based on the field and laboratory results, shallow foundation (reinforced strip, pad or raft) can be adopted for lightly loaded structures. Greater bearing capacity can be obtained by founding pad or strip on the bedrock within the southeastern part of the study area. Deep foundation in form of driven or bored pile should be adopted for heavily loaded building. A pile founding depth of about 33m depth anchored on the bedrock is recommended for the other areas.

Introduction

This work focuses on the evaluation of some relevant geotechnical characteristics of the subsoil of part of Federal University of Technology, Minna, Gidan Kwano campus with a view of utilizing the data obtained for recommending suitable foundation types and appropriate founding depths for the construction of new buildings

Study Area Description

The study area is located along Minna – Kataregi – Bida road and lies between latitude 9^0 28′ N to 9^0 37′ N and longitude 6^0 23′ E to 6^0 29′ E (figs 1&2). It consists of low lying terrains and few gentle hills. The southern and central parts of the site are relatively flat. The northern part of the site is remarkable for its rugged landscape and profuse outcrops. The area is drained by the seasonal Dagga river system and associated tributaries (Works Department, Federal University of Technology Minna, 1984).

 April 2008
ISSN 1596-9770

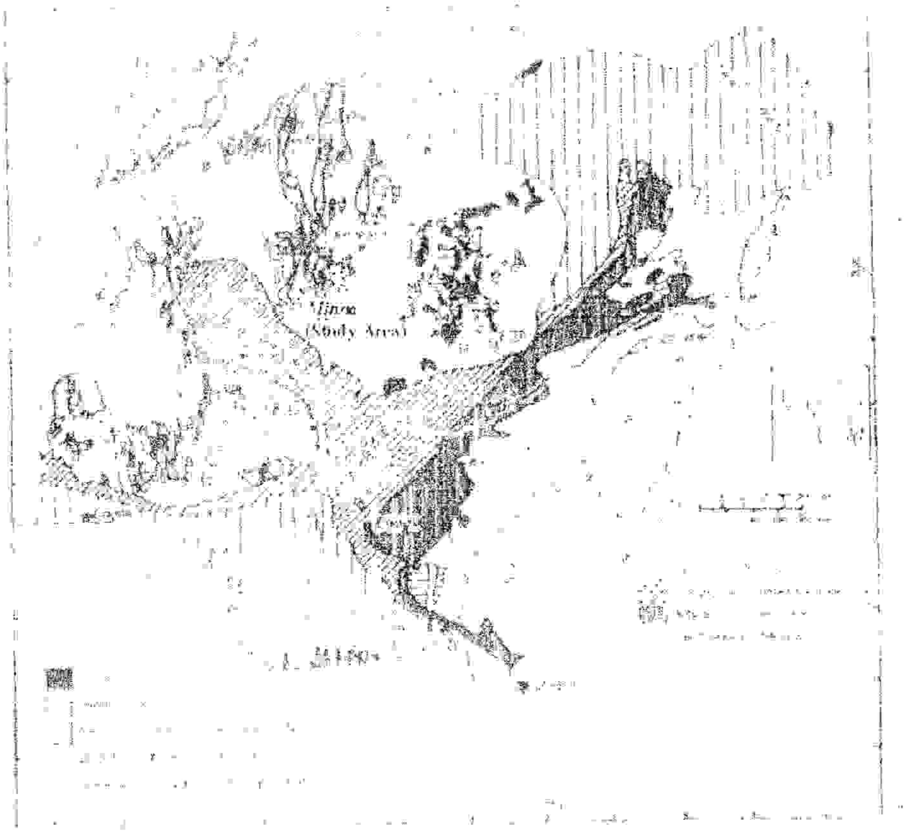

Fig 1 Generalized Geological map of Nigeria showing the location of the study area, Minna. (Source: Elueze, 1995)

General Geology of the Area

The area investigated is part of the north-western part of the Nigerian Basement Complex which is composed of three lithological units- migmatite gneiss complex, low grade schist belts and the older granite (Truswell and Cope, 1963, Ajibade, 1976)

Lithological and structural mapping revealed that the study area is underlain by monolithic granitic rock The rock can be grouped into porphyritic to coarse-grained granite and medium to fine grained granite (fig. 3)

Two sets of joints were identified. One set is trending N-S and the other E-W The former are common on the northern part while the later is frequent in the southern sector. Minor faults were observed on some outcrop.

Fig 4 illustrates a typical strata log of one of the borehole drilled

April 2008
ISSN 1596-9770

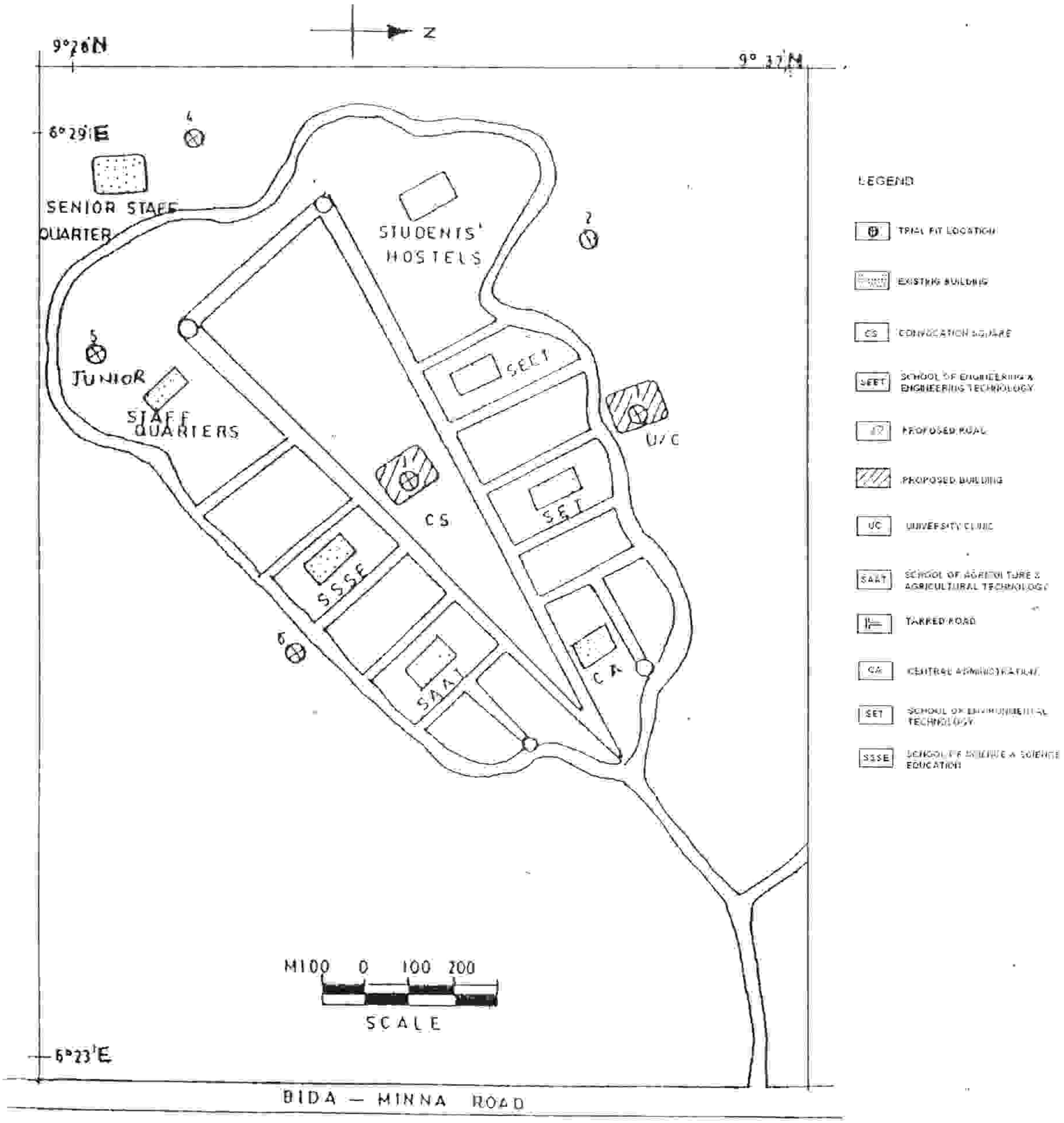

Fig. 2 Map of parts of Federal University of Technology, Minna Permanent site (Gidan Kwano campus) showing trial pit locations.

Methodology of Investigation

The sub-soil conditions was investigated by excavating six trial pits (fig. 2) from the existing ground level to between (1.0-1.5) meter according to British standard code of practice for site investigation (1981). Disturbed and undisturbed soil samples were collected from the trial pits and analyzed in Julius Berger Nigeria PLC laboratory, Minna and National Steel Raw Material Exploration Agency, Kaduna for relevant geotechnical analysis. The laboratory test was performed according to British standard methods of test for soils for civil engineering purposes (British Standard Institution, BS 1377: Part 1 - 9, 1990).

Dry sieve analysis was carried out in order to obtain the particle size distribution of the soil samples and was performed with a set of sieve sizes (19.00 mm, 9.50 mm, 4.75 mm, 2.36 mm, 1.18 mm, 0.600 mm, 0.425 mm, 0.300 mm, 0.15 mm, 0.075 mm) and mechanical sieve shaker.

Liquid limit was carried out with a liquid limit device (Casagrande cup). Plastic limit test was executed by kneading and rolling soil samples between fingers and thumb into about 6 mm diameter thread. Each thread was further rolled between fingertips on a clean flat glass paste with sufficient pressure to reduce the diameter into 3 mm. At exactly 3 mm, the soil paste starts to crumble and cannot roll further. The process was repeated until longitudinal and transverse cracks appear at a rolled diameter of 3 mm. Immediately, the moisture content of the crack thread was determined. Consolidation tests were performed on some selected undisturbed samples with an oedometer to determine the compressibility characteristics of the materials. Triaxial shear tests were performed on some chosen samples to estimate their in-situ shear strength characteristics. The soil pH was determined with the aid of a pH meter. The concentration of Cl^- in the soil was determined volumetrically.

The level of SO_4^{2-} in the soil samples was evaluated with an ultraviolet spectrophotometer.

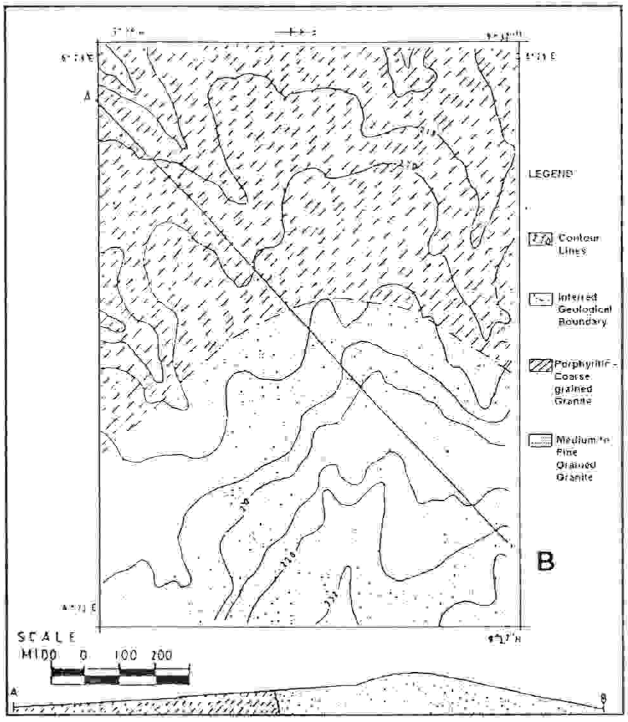

Fig. 3 Geological Map of parts of Federal University of Technology, Minna Permanent site (Gidan Kwano campus).

April 2008
ISSN 1596-9770

Results

Field Observations

The soil profile of trial pit 1 is shown in figs 5. The locations of the trial pits are summarized in Table 1. The soil profile of the trial pits reveals that the soil in the study area is heterogeneous with the exceptions of trial pits 4 and 5 that have some resemblance. This suggests that the soil around the staff quarters (senior and junior) is similar. The rate of excavating trial pits 2 and 4 was very slow thereby indicating a very stiff clay consistency. Although, the digging was undertaken during the dry season. The duration of excavating trial pits 1, 3, 5 and 6 was moderate thereby indicating a medium dense relative density (Clayton, et al., 1995). Excavation was terminated between (1.00 - 1.50) meters below the existing ground level when the bedrock was encountered during the excavation of trial pit 3, 5, and 6 or when digging was difficult as a result of the strength of the soil.

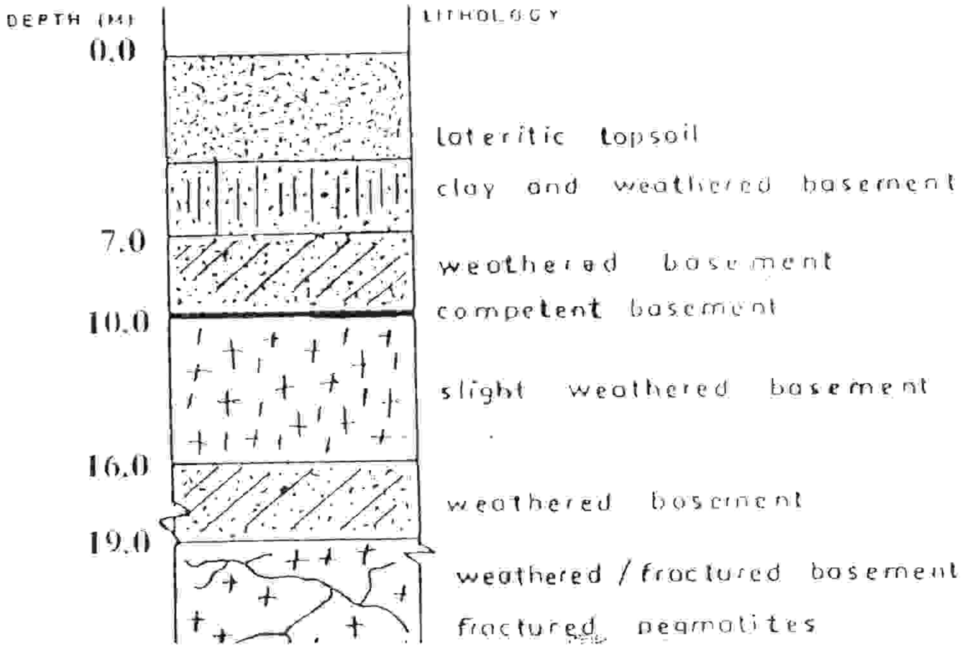

Fig. 4 Illustrates a Typical Strata Log of one of the Boreholes Drilled.

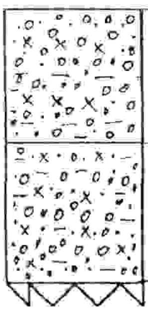

Fig 5 . Soil profile of trial pit 1

Table 1. Trial Pit Location

Trial Pit No.	Depth (m)	Location
1	0 – 1.0	Proposed site for the university clinic
2	0 – 1.0	Around the student's hostel
3	0 – 1.5	Proposed site for convocation square
4	0 – 1.5	Around senior staff quarters
5	0 – 1.0	Between senior staff and junior staff quarters
6	0 – 1.0	Adjacent to the School of Science and Science Education (SSSE). School of Agriculture and Agricultural Technology (SAAT).

Laboratory Results

Sieve Analysis

The results of the sieve analysis are summarized in table 2. A typical particle size distribution curve is illustrated in fig. 6. Two types of curves were identified Soil samples with serial number 7, 8, 9, 10, 12, 16, 17 and 20 have the ratio of sand > clay + silt > gravel. The other soil samples have the proportion of clay + silt > sand > gravel.

Atterberg Limits

The results of the Atterberg limits are presented in table 3. Figs 7 and 8 illustrate a typical plasticity chart obtained from the study area. Generally, the soil samples are of low plasticity as reflected in trial pits 1, 3, 4, 5, 6 and 2, sample no.1. The samples collected at (0.5 and 1.0) meters are of intermediate plasticity. The shrinkage potential of soil samples no. 5, 6, 7 and 19 are ranked medium while the remaining ones are of low shrinkage potentials. The mean value of the liquid limit, plastic limit and plasticity index is 27.7%, 20.7% and 7.0% respectively. The liquid limit ranges from 18.0% - 43.0%, the plastic limit is of the order of 13.8% - 28.3% while the plasticity index varies from 2.1% - 18.1%.

Table 4 summarizes the soil sample classification.

Triaxial Test

The result of quick undrained triaxial compression test is contained in table 3 and typical graph of total stress Mohr's circles is illustrated in fig 9. The cohesion (c) ranges from 130KN/m^2 to 164KN/m^2 while the angle of internal friction (Ø) was found to be 8^0.

Consolidation Test

The results are presented in table 3 and a representative plot of thickness against square root of time obtained from consolidation test is illustrated in fig. 10. The plot of void ratio against pressure is exemplified in fig. 11. The coefficient of consolidation (C_v) varies from 1.47m^2/yr to 2.57m^2/yr. The coefficient of volume compressibility (M_v) ranges from 0.2m^2/MN to 1.15m^2/MN and the compression index (Cc) is of the order of 0.32 to 0.38.

Chemical Analysis

The soil pH ranges from 6.95 to 7.29 indicating a neutral condition. The concentration of sulphate (SO_4^{2-}) in the soil sample varies from 0.0022ppm to 0.0012ppm while the level of chloride (Cl^-) is of the order of 0.0078ppm to 0.0017ppm. Both the sulphate and chloride concentration are below the normal concentration in uncontaminated soils when compared with greater London council guidelines for classification of contaminated soil as cited by Curtin et al. (1997). Excessive SO_4^{2-} content will have aggressive effect on the cement used in constructing the foundation of the building. Too much chloride content could lead to rusting (corrosion) of the metallic component of the foundation (Tomlinson, 1999).

April 2008
ISSN 1596-9770

Table 2 Sieve Analysis Result

S/No.	Trial Pit No.	Sample No.	Depth (m)		Sieve Analysis (% Passing)									
				Sieve Size→ (mm)	19.00	9.50	4.75	2.36	1.18	0.600	0.425	0.300	0.150	0.075
1	1	1	0.0		100.00	97.2	90.02	85.26	80.94	74.40	69.80	61.96	46.68	40.06
2	1	2	0.5		100.00	94.36	59.46	29.00	24.62	23.04	22.36	21.58	20.10	19.16
3	1	3	1.0		100.00	89.10	56.38	38.18	31.48	28.10	27.12	25.62	23.12	21.90
4	2	1	0.0		100.00	100.00	100.00	99.80	98.86	94.92	91.50	85.12	68.88	60.04
5	2	2	0.5		100.00	100.00	98.84	97.06	92.20	84.70	80.12	74.42	64.18	59.50
6	2	3	1.0		100.00	100.00	98.54	96.28	92.52	86.88	83.28	78.32	68.48	64.02
7	3	1	0.0		100.00	100.00	99.28	94.48	84.78	75.20	69.90	62.54	51.64	48.42
8	3	2	0.5		100.00	96.92	99.96	82.62	74.02	67.88	64.38	59.50	49.70	43.62
9	3	3	1.0		100.00	100.00	99.44	94.62	79.56	63.84	55.18	44.68	28.66	22.32
10	3	4	1.5		100.00	97.92	96.30	91.18	83.52	76.02	71.48	65.30	52.96	44.56
11	4	1	0.0		100.00	100.00	100.00	99.74	98.56	91.90	83.76	72.22	49.76	39.46
12	4	2	0.5		100.00	99.64	98.98	98.36	96.60	90.06	81.34	69.90	50.46	40.46
13	4	3	1.0		100.00	100.00	99.64	98.58	95.66	88.92	82.80	75.40	63.58	56.82
14	4	4	1.5		100.00	93.96	84.78	84.14	80.66	75.02	69.94	64.18	55.76	52.68
15	5	1	0.0		100.00	87.38	82.76	78.66	74.60	69.74	65.94	59.06	46.94	40.88
16	5	2	0.5		100.00	100.00	98.84	92.40	81.64	64.72	59.70	51.34	38.98	32.84
17	5	3	1.0		100.00	100.00	99.76	95.00	83.38	71.22	63.88	54.84	39.92	32.56
18	6	1	0.0		100.00	98.90	89.50	98.80	96.24	92.06	86.56	77.10	60.62	55.34
19	6	2	0.5		100.00	100.00	99.94	99.32	97.48	93.40	89.40	83.62	74.22	7.12
20	6	3	1.0		100.00	91.84	76.82	63.82	53.66	45.06	40.32	35.30	27.90	23.64
ARITHMETIC MEAN →					100.00	97.36	91.66	85.82	80.10	73.00	67.92	61.10	49.13	43.42
RANGE →						89.10-100.00	56.30-100.00	29.00-99.80	24.62-99.86	23.04-94.92	22.36-91.50	21.58-85.12	20.10-74.22	19.16-70.12

Table 3 Summary of Results of Laboratory Analysis

S/No.	Trial Pit No.	Sample No.	Depth (m)	Atterberg Limit LL	PL	PI	SP	Triaxial Test C_u KN/m^2	Ø (Kpa)	Consolidation Test C_v M^2/Yr	M_v m^2/MN	C_c
1	1	1	0.0	18.4	15.7	2.7	Low					
2	1	2	0.5	34.9	23.0	11.9	Low					
3	1	3	1.0	32.6	22.3	10.3	Low					
4	2	1	0.0	22.9	18.9	4.0	Low					
5	2	2	0.5	43.0	26.5	16.5	Medium					
6	2	3	1.0	42.2	24.1	18.1	Low	164	8	2.57	1.15	0.32
7	3	1	0.0	28.3	23.9	4.4	Low					
8	3	2	0.5	26.0	21.5	4.5	Low					
9	3	3	1.0	26.0	22.9	3.1	Low					
10	3	4	1.5	25.0	21.1	3.9	Low					
11	4	1	0.0	19.0	13.8	5.2	Low					
12	4	2	0.5	18.0	13.9	4.1	Low					
13	4	3	1.0	27.0	17.6	9.4	Low	130	8	1.47	0.20	0.38
14	4	4	1.5	27.0	18.2	8.8	Low					
15	5	1	0.0	26.7	21.0	5.7	Low					
16	5	2	0.5	30.4	28.3	2.1	Low					
17	5	3	1.0	24.2	21.5	2.7	Low					
18	6	1	0.0	23.0	17.3	5.7	Low					
19	6	2	0.5	35.0	23.5	11.5	Medium					
20	6	3	1.0	24.6	19.7	4.9	Low					
ARITHMETIC MEAN →				27.7	20.7	7.0		147	8	2.02	0.68	0.35
RANGE →				18.0-43.0	13.8-28.3	2.1-18.1		130-164	-	1.47-2.57	0.20-1.15	0.32-0.38

April 2008
ISSN 1596-9776

Table 4 Soil Sample Identification and Classification

S/No	Trial Pit No	Sample No	Depth (m)	Unified Soil Classification	British Soil Classification	Soil Description
1	1	1	0.0	SC/ML	CLG/ML	Brown, gravelly, clayey, sily, fine to coarse sand.
2	1	2	0.5	GC/CL	CLG	Brown, lateritic, silty, clayey, sandy, fine to medium gravel.
3	1	3	1.0	GC	GCL	Brown, lateritic, silty, clayey, sandy, fine to medium gravel.
4	2	1	0.0	ML	MLG	Dark brown, sandy, clayey silt.
5	2	2	0.5	CL	CIG	Brown, gravelly, sandy, silty clay.
6	2	3	1.0	CL/GC	CIG	Brown, gravelly, sandy, silty clay.
7	3	1	0.0	ML	SCL/ML	Brown, gravelly, clayey, silty sand.
8	3	2	0.5	SC/GC	SCL/MLG	Brown, gravelly, clayey, silty sand.
9	3	3	1.0	SC/GC	SCL/MLG	Brown. clayey, silty, gravelly, fine to coarse sand.
10	3	4	1.5	SC/GC	SCL/MLG	Brown, clayey,silty, gravelly, fine to coarse sand.
11	4	1	0.0	SC/SM	SCL/ML	Brown, clayey, silty, fine to coarse sand.
12	4	2	0.5	SC/SM/GC	SCL/ML	Brown, gravelly, clayey, silty, fine to coarse sand.
13	4	3	1.0	CL/GC	SCL/MLG	Brown, gravelly, sandy, silty clay.
14	4	4	1.5	CL/GC	CLS/CL	Reddish brown, gravelly, sandy, silty clay.
15	5	1	0.0	CL/GC	SCL/MLG	Brown, gravelly, clayey, silty sand.
16	5	2	0.5	SC/SM/GC	SCL/ML	Brown, gravelly, clayey, silty, fine to coarse sand
17	5	3	1.0	SC/SM/GC	SCL/ML	Brown, gravelly, clayey, silty, fine to coarse sand.
18	6	1	0.0	CL/GC	SCL/ML	Brown, gravelly, sandy, clayey silt.
19	6	2	0.5	CL/GC	CLS/CL	Brown, gravelly, sandy, silty clay.
20	6	3	1.0	SC/SM/GC	GCL/ML	Brown, clayey, silty, gravelly, fine to coarse sand.

April 2008
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FIG. 8 TYPICAL PLASTICITY CHART OBTAINED FROM TRIAL PIT 2.

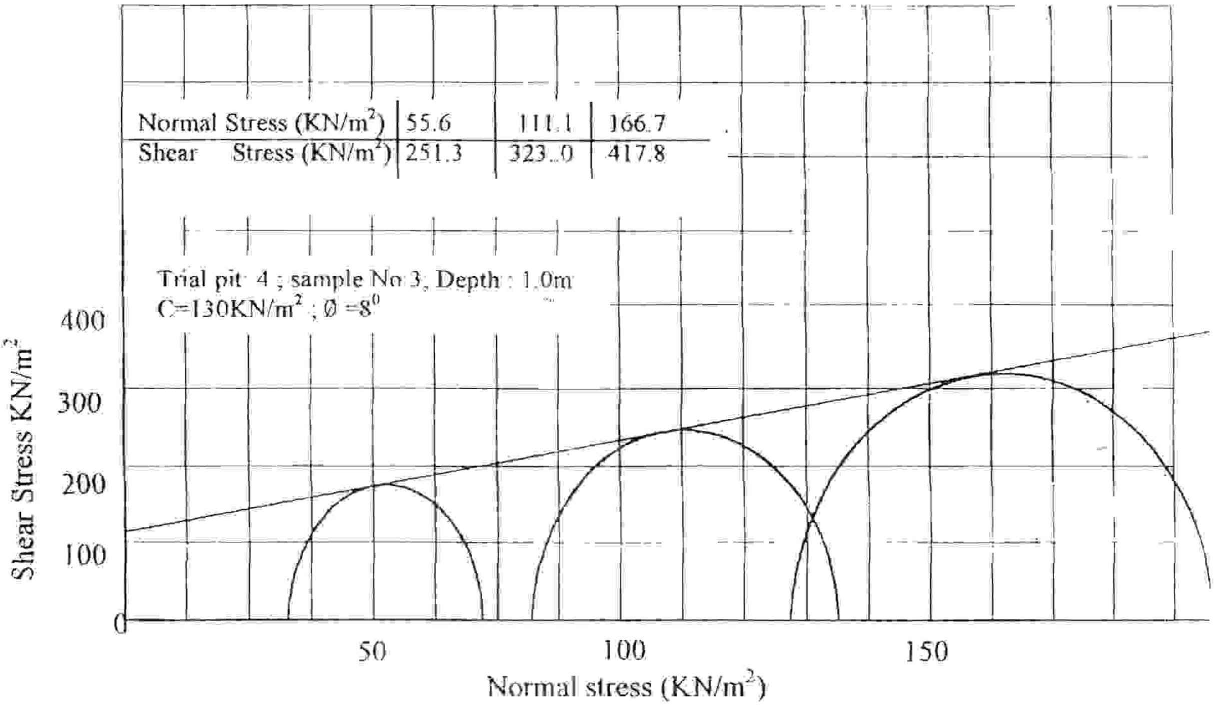
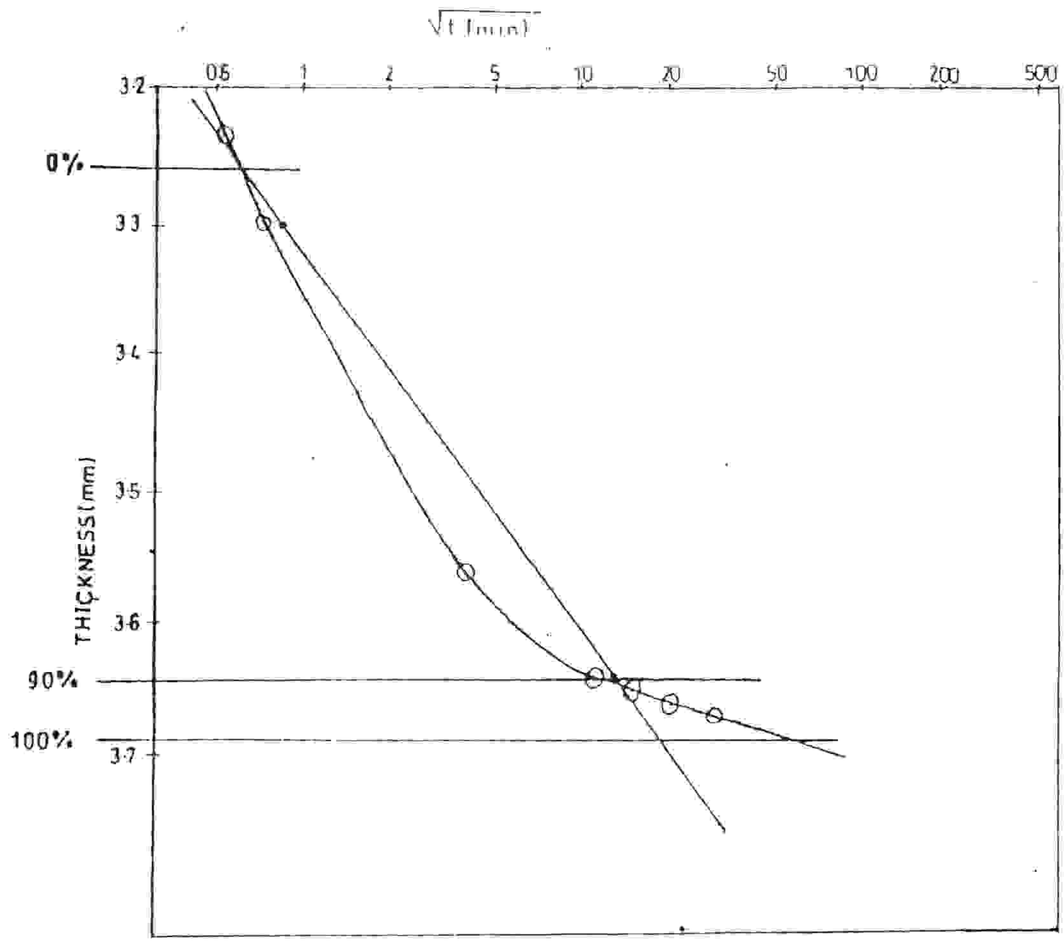


FIG. 9 TOTAL STRESS MOHR'S CIRCLES OBTAINED FROM QUICK-UNDRAINED TRIAXIAL COMPRESSION TEST.



Trial Pit 4
Sample No 3
Depth 1.0m

Height of Sample 0.19cm
Compression area $1.18M^2$
Cv = $1.47m^2$/ Year

FIG. 10 PLOT OF THICKNESS AGAINST SQUARE ROOT OF TIME OBTAINED FROM CONSOLIDATION TEST.

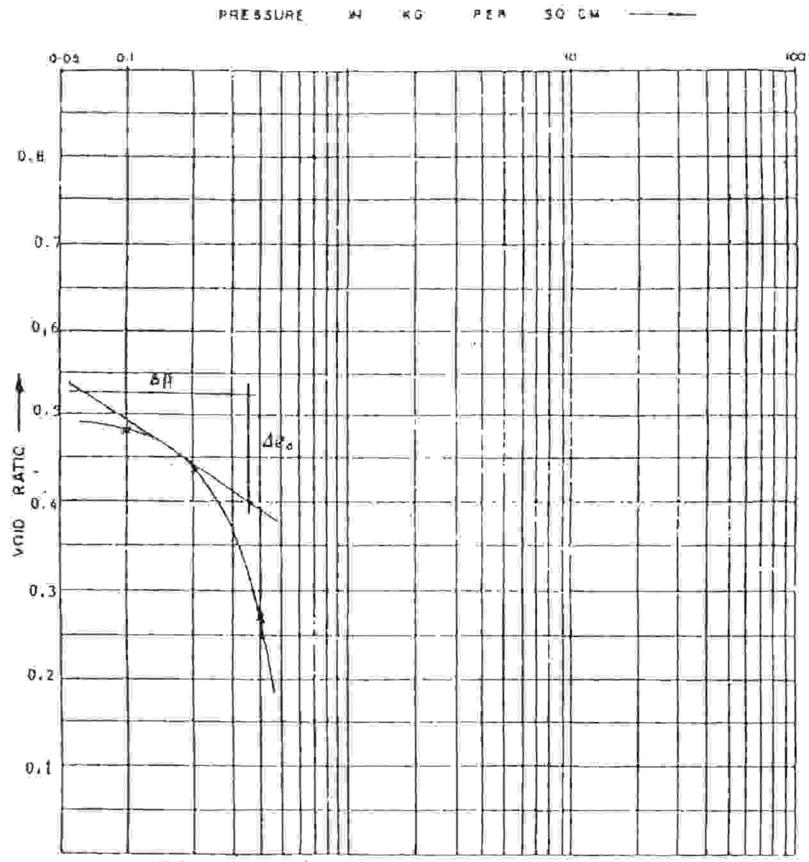


FIG. 11 PLOT OF VOID RATIO AGAINST PRESSURE

Discussion

Foundation Recommendation

The foundation analysis is based on the results obtained from the field investigation and laboratory tests using the regulations stipulated by British standard code of practice for foundation (1986).

Shallow (spread) Foundation

Shallow foundation can be considered for lightly loaded structures for example, bungalows and classroom blocks. Generally, reinforced strip, pad or raft foundation can be adopted Foundation can be placed between 0.50 m and 1.0 m below the existing ground level in areas covered by trial number 1, 3, 5 and 6 (fig. 3) within the clayey, silty, gravelly, fine to coarse sand As a guide in design, for foundation not exceeding 1.0 m in diameter (strip and pad), an allowable bearing pressure of 150KN/m^2 should be utilized in foundation design with total settlement not exceeding 25mm and negligible differential settlement (Tomlinson, 1999) For foundation width greater than 1.0 m or of about 4.0 m, an allowable bearing pressure of 100 KN/m^2 should be adopted. The total settlement expected will not exceed 25mm (Curtin, et al., 1997).

In areas covered by trial pits 2 and 4 where clayey layer was encountered, the net ultimate bearing capacity, that is, the net loading intensity at which the ground fails in shear for a particular foundation (Tomlinson, 1999) was calculated for strip, pad and raft foundation. The net ultimate bearing capacity of 314 KN/m^2 and 304 KN/m^2 were estimated. Approximately 40% of the net ultimate bearing capacity was adopted as the allowable bearing pressure to minimize shearing and settlement effect. Therefore, an allowable bearing pressure of 125 KN/m^2 is advised for strip and pad of 1.0 m width with total settlement not exceeding 25 mm and negligible differential settlement. The foundation should be placed between 0.5 m and 1.0 m below the existing ground level and within the gravelly, sandy, silty, clay. For raft foundation, an allowable bearing pressure of 120 KN/m^2 should be adopted with negligible total and differential settlements.

Areas covered by trial pits 3, 5 and 6 (south eastern part of the study area) where the rock level was encountered between (1.0 – 1.5) meters, pad or strip can be founded on the bedrock to minimize total differential settlement.

Deep (Piled) Foundation

If the proposed structure for example, multi-storey building will exert pressure in excess of the recommended allowable bearing pressures in areas covered by trial pits 1, 2, 4 and central administration, deep foundation should be considered. Generally, the types of foundation that can be adopted are the driven or bored piles, which can be designed as friction, end bearing piles, or a combination of the two. Pre-cast pile, steel-casing piles filled with concrete or reinforced cast in-situ piles of appropriate dimension can be used. The dimension will depend on the proposed structure. Driven piles should be avoided close to existing structures to prevent the buildings from vibration, which could lead to damage. The pile should be anchored on the bedrock at least 0.5 m beneath the rock level or where piling rig reaches its maximum driving capacity. In fig 4, the fresh basement (granite) was encountered between (31-34) meters below the existing ground level (Jimoh, 1998). Therefore, a pile founding depth of 33m is recommended. Fresh granite has presumed allowable bearing pressure of 10,000 KN/m^2 (British Standard code of practice for foundation, 1986).

Conclusion

The knowledge of the geotechnical characteristics of Federal University of Technology, Minna permanent site as obtained from geological field work, excavation of trial pit, borehole drilling log and laboratory analysis of recovered soil samples have provided valuable data that can be used for designing and constructing the foundation of future civil engineering structure.

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