資料－５　ボーリング調査結果

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MESSRS YACHIYO ENGINEERING CO. LIMITED

PROPOSED PROJECT FOR RURAL ELECTRIFICATION
AT AWE CITY, NASARAWA STATE,
FEDERAL REPUBLIC OF NIGERIA

REF.: S.10901/JUNE, 2000

REPORT ON SUBSOIL INVESTIGATION

Carried Out By:-

FOUNDATION ENGINEERING SERVICES LIMITED,
P. O. BOX 2100,
LAGOS.

FE

MESSRS YACHIYO ENGINEERING CO. LIMITED

PROPOSED PROJECT FOR RURAL ELECTRIFICATION

AT AWE CITY, NASARAWA STATE,

FEDERAL REPUBLIC OF NIGERIA

REPORT ON SUBSOIL INVESTIGATION

1. INTRODUCTION

Further to your letter of reference YEC-BRG-FDN01 dated 18th May, 2000, Foundation Engineering Services Limited carried out a subsoil investigation at Awe city in Awe Local Govt. area of Nasarawa State for the above proposed project. The purpose of the investigation was to provide data on subsoil conditions for foundation design.

The following is our report on the investigation.

2. SCOPE OF INVESTIGATION

2.1 Site Work

The site work was carried out between 5th and 6th June, 2000. The defined scope of site work required comprised 2 No. shell and auger borehole terminated at 2.5m and 3.0m depths respectively on encountering bedrock and the survey of the boring position to

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determine the height above Mean Sea Level (MSL) with reference to an established bench mark.

A pilcon Wayfarer 1500 rig with B.S. 5930 shell and auger percussion boring techniques was used to bore through the soil deposits. Both disturbed and undisturbed soil samples were taken and standard penetration tests (SPT) carried out at regular intervals of 1.0m depth as appropriate.

An area map showing Awe city is presented as Figure 1 while a site plan (based on the sketched site layout drawing provided by the client) indicating approximate positions of the boreholes as selected by yourselves and set out by ourselves is presented as Figure 2.

Borehole log giving details of the strata encountered at the site are presented as Figures 3 and 4.

All depths referred to in this report are below ground surface at the time of the investigation and are approximate.

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2.2 Laboratory Testing

Laboratory tests relevant to the engineering objectives of the investigation were Scheduled on selected samples retrieved from the borehole. The tests were carried out in general accordance with B.S. 1377; 1990. "Method of Test for Soils for Civil Engineering Purposes"; Parts 1 - 9 unless otherwise stated. The results are presented in tabular and graphical forms in the Appendix.

The following tests were carried out:-

3 No.	Particle size distribution by wet sieving
1 No.	Hydrometer Analysis
1 No.	Atterberg limits determination on material passing 425 micron sieve
1 No.	Quick Undrained Triaxial Compression Test on 38mm diameter undisturbed sample
1 No.	Unconfined compression Test
3 No.	Natural Moisture Content
1 No.	One-dimensional Oedometer Consolidation Test to determine compressibility characteristics. In calculating the coefficient of consolidation (Cv). "The Square Root of Time Fitting" method was adopted

1 No. Chemical Analysis of soil samples for hydrogen ion concentration (pH) and soluble sulphate content.

3.0 GEOLOGY OF THE SITE (AWE CITY, NASARANA STATE)

The site is generally flat and uncultivated with grown grasses and few scattered trees. The 1:2,000,000 Geological Map of Nigeria compiled by the Geological survey of Nigeria, 1974 Edition, indicates that the site is underlain by shale and limestone. The results of the investigation are generally concordant with the overburden soils associated with the description of the site geology.

4.0 SUBSOIL AND GROUNDWATER CONDITIONS

Details of the subsoil strata encountered during boring are given on the borehole logs. However, the subsoil sequence may then be generally summarised as follows:-

Depth Below Ground Level (m)		Generalised Strata Description
From	To	
(Range)*	(Range)*	
Ground Level	0.5	Loose silty SAND with gravel (f) [TOPSOIL]

0.5	2.5 (Borehole 1 Termination)	Medium dense clayey silty SAND (c.m.f) with gravel (f), underlain by weathered rock.
2.5	3.0 (Borehole 1A Termination)	Firm sandy (c.m.f) silty CLAY becoming hard with weathered limestone

*Range is as encountered in the borehole. Variations in strata thickness and depths away from the boreholes are likely.

Groundwater seepage was not encountered in the borehole. However, indications from local observations are that the groundwater level could vary approximately be between 8.0m and 10.0m depths. Seasonal variations in groundwater level will occur, with the possible development of perched watertable within the clayey or indurated layers during or immediately after the wet season.

5.0 LABORATORY TEST RESULTS

Particle size analysis carried out on samples of the overburden sandy clay gave the range of gravel fraction to be 7% to 25%, sand 52% to 69%, silt 6% to 24% clay 0% to 35% by weight. Detailed results are presented on the summary sheet and

graphically on the particle size distribution curves in the Appendix.

The index properties of the clayey deposits were investigated by means of Atterberg limits tests on some samples. The natural moisture content (W) ranged between 16% to 20%. Also liquid limit (wL) was 42%, while the plastic limit (WP) was 16%. Therefore the plasticity index (IP) was 26%. This indicate low plasticity.

The liquidity index (IL) which is equals to the moisture content (W) minus plastic limit (WP) divided by plasticity index (IP) for the various samples tested was computed. A normally consolidated clay has a moisture content (W) approaching the liquid limit with a liquidity index (IL) tending to unity, while an over-consolidated clay has a moisture content around the plastic limit with a liquidity index of approximately zero or negative. The sample considered gave liquidity index value of 0.15 indicating an appreciable degree of over-consolidation.

The shear strength of the cohesive clay deposits were determined by means of Quick Undrained Triaxial Compression Test and Unconfined Compressive Test on undisturbed samples. The undrained cohesion (Cu) was indicated to be 50 kN/m^2 and angle of

internal friction (Øu) of 9 degrees. The unconfined compressive test was indicated to be 65KN/m^2. This result indicate firm consistency and is tabulated in the Appendix.

The bulk wet density of the clayey deposits was 2.03 mg/m^3.

Deformation characteristics of the clay deposits were determined in oedometer apparatus. The coefficients of consolidation (Cv) and compressibility (Mv) of the overburden pressure is presented on the summary tables, while the graph of voids ratio (e)/log of effective pressure (P) relationship for the sample tested is presented in the Appendix. The results indicates the clay deposits to be of medium to high compressibility.

The aggressiveness of the soil samples to concrete was assessed by the determination of hydrogen ion concentration (pH) and soluble sulphate content of 1 No. sample. The pH value was indicated to be 6.0 indicating slightly acidic conditions, with very small soluble sulphate content (0.002gr/litre).

From the survey work, carried out at the boring position (Borehole 1A).

The following values are tabulated below in Table 1:-

Station	Starting Point and Height above the Mean Sea Level (MSL) (m)	Distance Covered (km)	Height of Boring Station above the Mean Sea Level (MSL) (m)	Height of Temporary Bench Mark (TBM) (m)
Awe City Borehole 1A	Fixed Land Mark 381.25m	14	403.562	TBM1 = 405. TP1 = 204.299

Table 1

Note: More detailed survey report is presented in the Appendix.

6.0 DISCUSSION

6.1 Design Details

It is understood that it is proposed to install a transformer of about 12 ton (120kN). No further details have been made available to us. However, for the purpose of this report, we have assumed a maximum overall ground loading of 60 kN/m^2.

The following comments and recommendations are based on the borehole logs and on the results of the laboratory tests.

6.2 Shallow Foundation

The results of in-situ and laboratory test carried out indicated the presence of a medium dense clayey silty sand within the top 1.5m and firm silty clay with decomposed rock to 3.0m depth within which a shallow foundation can be set.

Generally as a guide, it is estimated that the net allowable bearing pressures that may be imposed at different founding depths are as shown in Table 2 below.

These Figures have taken into consideration the relief provided by the overburden assumed to be removed above the founding level.

Founding Depth (m)	Allowable bearing Pressure (kN/m^2)
1.0	80
2.0	100
3.0	200

Table 2. Estimated Allowable Pressure for shallow Foundation.

However, it is recommended that reinforced concrete strip or pad foundations may be adopted for supporting the proposed structures at this site. The foundations should not be less than 1.0m wide, set in the upper virgin firm sandy clay and not shallower than 1.0m depth in order to avoid problems of seasonal moisture variation.

6.3 Settlement

Settlement due to consolidation of clayey strata beneath foundation level will be dependent on the foundation type and width, its founding depth, the bearing pressure imposed and care taken in excavating and preparing the formation level.

Settlement of strip or pad foundations constructed to the standards, loading and depths stated above is estimated to be less than 20mm with differential settlement not exceeding 10mm.

6.4 Foundation Preparation

The base of the foundation excavation must be carefully probed and inspected for soft pockets which, if encountered, must be completely removed and replaced with well compacted relatively dry lean mix concrete.

Immediately after preparation, the foundation level must be protected with blinding layer of concrete as the soil may soften if left exposed or if ingress of water is allowed.

It is our experience that the type of sandy clay encountered at this site is very susceptible to softening and disturbance by the ingress of water and by construction processes. It is therefore most important that great care be taken not to disturb the soil

at or below foundation level during excavation and that it must be kept dry at all times.

Backfilling to the sides of the foundation should be placed to ground level as soon as possible following casting of the foundation. Backfilling of excavations around completed foundations should be with suitable material placed in thin layers not exceeding 200mm thickness and compacted to a high standard.

Backfilling of foundations in cohesive deposit such as encountered at this site should be with materials which, when compacted as recommended above, will be less permeable than the surrounding ground. This will prevent seepage through or between the backfill and the original ground and avoid softening of the clay at or below foundation level.

7.0 GENERAL

The subsoil conditions are indicated to be slightly acidic, with negligible concentrations of soluble sulphates. Ordinary Portland cement may be used for buried concrete but a rich, dense mix is recommended.

We strongly recommend that the design and construction of all foundation and earthworks be carried out in accordance with a good engineering practice as embodied in recognised Codes of Practice such as the British Standards Institution's B.S. 8004: 1986, Code of Practice for Foundations and B.S. 6031: 1981, Code of Practice for Earthworks.

We trust you find the contents of this report of assistance and assure you of our best attention at all times.

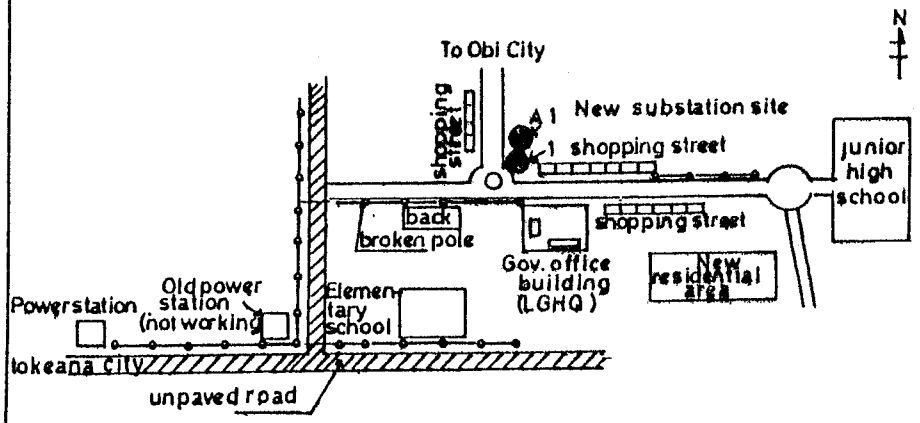
S. Adekoba,
Civil Engineer.

Prince Wale Ajayi-Fajomodu,
Managing Director.

FOUNDATION ENGINEERING SERVICES LIMITED,
P. O. BOX 2100,
LAGOS.

REF.:S10901/JUNE, 2000.

FIG. 2



Proposed Project For Rural Electrification
At Awe City, Nasarawa State.

LOCATION MAP

KEY

● :- Borehole postion.

(S10901)

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FIG. 3A

BOREHOLE LOG

LOCATION : PROPOSED RURAL ELECTRIFICATION PROJECT AT AWE CITY, NASARAWA STATE
JOB No : S10901
BOREHOLE DIA : 0.15m
DATE (Start) : 6/6/2000
BOREHOLE No : 1A (AWE CITY)
GROUND LEVEL : 403.562m (ABOVE MSL)
GROUND WATER : NOT ENCOUNTERED

DEPTH (m)	LEGEND	SAMPLE No	DESCRIPTION	BLOWS FOR S.P.T. SPOON FOR 0.30m DRIVE (N) 10 20 30 40 50
0				
		●1	Loose, dark brown silty SAND (c.m.f) with gravel (f) (TOPSOIL)	
1		+2		15
		●3	Medium dense, brown clayey silty SAND (c.m.f) with occasional gravel (f)	
2		+4		15
		15	Firm mottled grey and brown sandy (c.m.f) silty CLAY becoming Hard with highly weathered limestone at 3.0m depth	
3		+6		51
			Borehole terminated at 3.0m depth	
4				
5				
6				
7				

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FIG. 3.

BOREHOLE LOG

LOCATION : PROPOSED RURAL ELECTRIFICATION PROJECT AT AWE CITY, NASARAWA STATE

JOB No : S10901

BOREHOLE DIA : 0.15m

DATE (Start) : 6/6/2000

BOREHOLE No : 1 (AWE CITY)

GROUND LEVEL : –

GROUND WATER : NOT ENCOUNTERED

DEPTH (m)	LEGEND	SAMPLES No	DESCRIPTION	BLOWS FOR S.P.T. SPOON FOR 0.30m DRIVE (N) 10 20 30 40 50
0				
		•1	Loose, dark brown silty SAND (c.m.f) with gravel (f) and pockets of sand stone (TOPSOIL)	
1		+2		
		•3	Medium dense mottled grey and brown clayey silty SAND (c.m.f) with gravel (f). Encountered highly weathered limestone at 2.5m depth	
2		+4		
		•5		
			Borehole terminated at 2.5m depth	
3				
4				
5				
6				
7				

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LOCATION: PROPOSED RURAL ELECTRIFICATION PROJECT AT AWE CITY, NASARAWA STATE

CONTRACT No: S10901

SHEET:- 1 OF 1

Summary of Laboratory Test Results.

BOREHOLE/ SAMPLE No.	TYPE	DEPTH m	PARTICLE SIZE DISTRIBUTION % PASSING 2·00 mm	425 µm	63 µm	2 µm	NAT M.C % dw	ATTERBERG LIMITS LL % dw	PL % dw	PI % dw	γB Mg/m³	SG	QUICK UNDRAINED TRIAXIAL TESTS dia (mm) type	σ3 kN/m²	Cu kN/m²	φu deg	LAB VANE Su kN/m²	OEDOMETER CONSOLIDATION STRESS RANGE kN/m²	mv m²/MN	Cv m²/yr	pH	SO3 (s) gr/litre	SO3 (w) pp 10⁵	COMMENTS OTHER TESTS
1A/2	D	1.0	93	39	24		18														6.0	0.002		
1A/3	D	1.5	75	25	12		16																	
1A/5	U	2.5	93	58	41	35	20	42	16	26	2.03		38	100	50	9		50–100	0.355					65
														200				100–200	0.242					
														400				200–400	0.186					

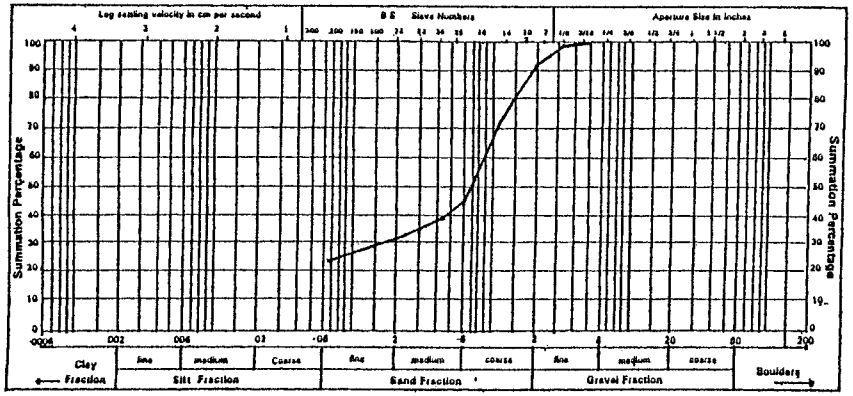
PARTICLE SIZE DISTRIBUTION

CONTRACT: S10901 PROPOSED RURAL ELECTRIFICATION PROJECT AT AWE CITY, NASARAWA STATE

DATE: JUNE, 2000

BOREHOLE/SAMPLE NO: 1A/2 DEPTH: 1.0m

LOSS ON PRETREATMENT: -

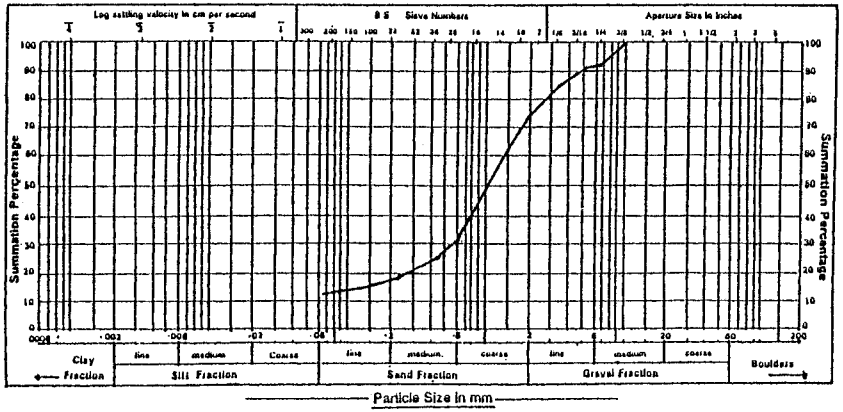


CONTRACT: S10901 PROPOSED RURAL ELECTRIFICATION PROJECT AT AWE CITY, NASARAWA STATE

DATE: JUNE, 2000

BOREHOLE/SAMPLE NO: 1A/3 DEPTH: 1.5m

LOSS ON PRETREATMENT: -



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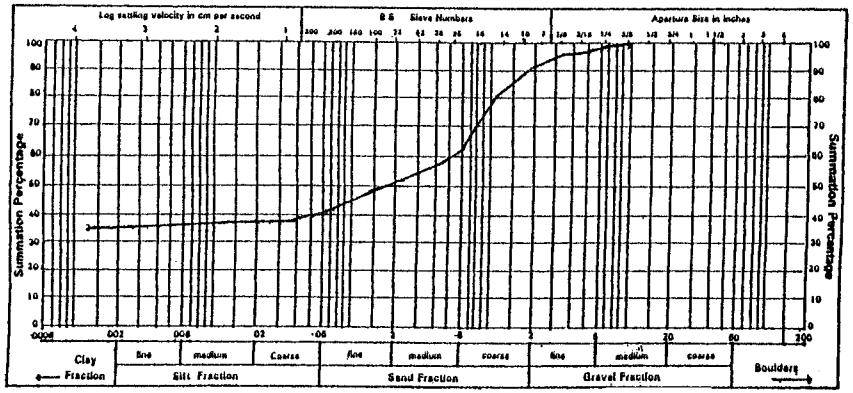
PARTICLE SIZE DISTRIBUTION

CONTRACT: S10901 PROPOSED RURAL ELECTRIFICATION PROJECT AT AWE CITY, NASARAWA STATE

DATE: JUNE, 2000

BOREHOLE/SAMPLE NO: 1A/5 DEPTH: 2.5m

LOSS ON PRETREATMENT: -

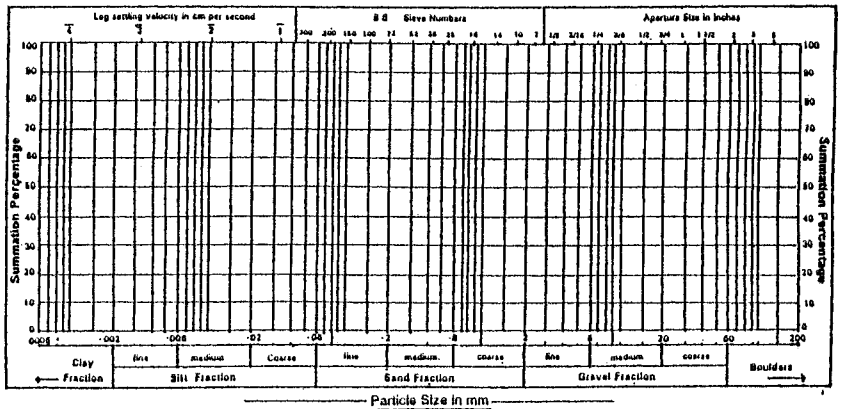


CONTRACT:

DATE:

BOREHOLE/SAMPLE NO: DEPTH:

LOSS ON PRETREATMENT:



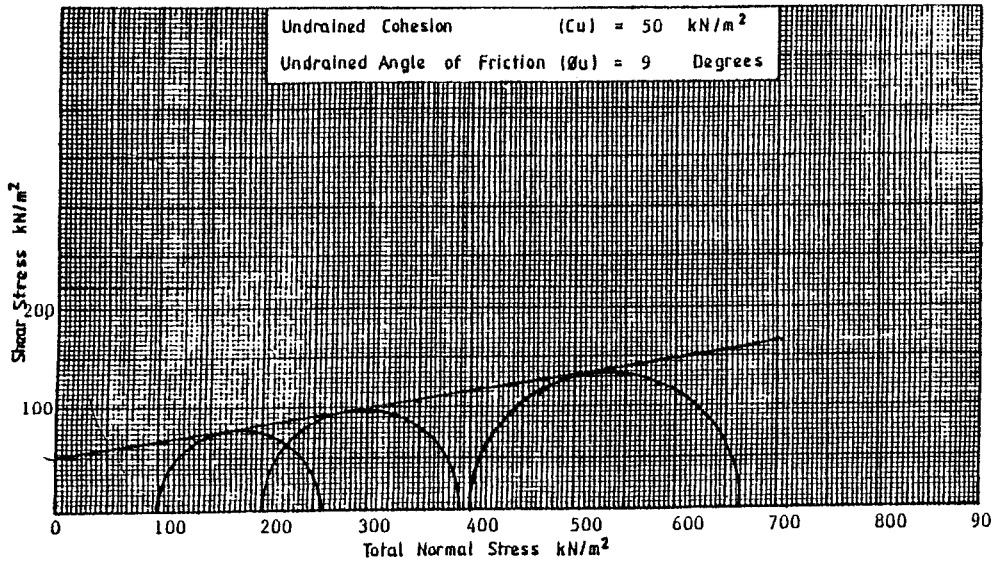
FOUNDATION ENGINEERING SERVICES LTD. FIG. A3

QUICK UNDRAINED TRIAXIAL COMPRESSION TEST

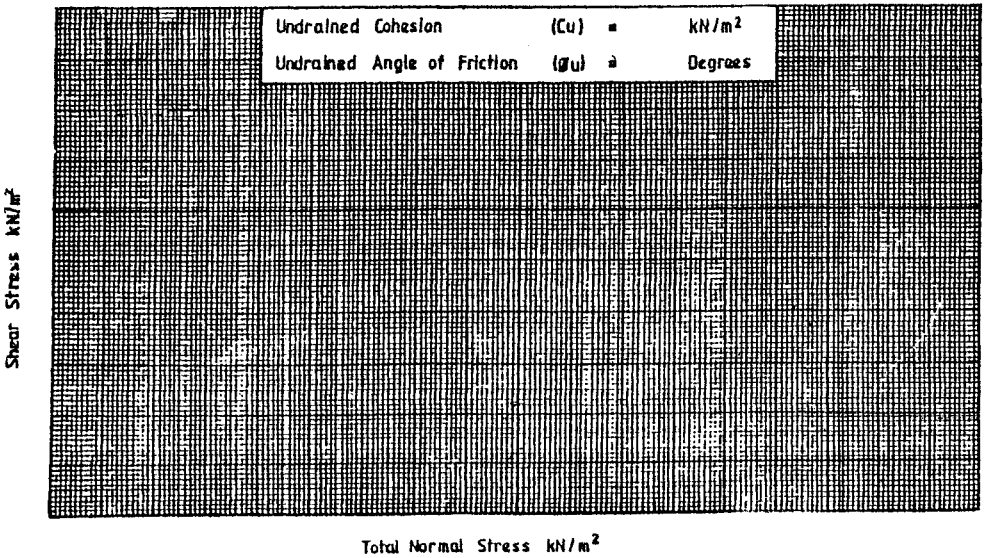
MOHR CIRCLES DIAGRAM

LOCATION. PROPOSED RURAL ELECTRIFICATION PROJECT AT AWE CITY, NASARAWA STATE
JOB No S10901
DATE OF TEST JUNE, 2000

BOREHOLE No 1A
SAMPLE No. 5
DEPTH 2.5m



BOREHOLE No. SAMPLE No. DEPTH



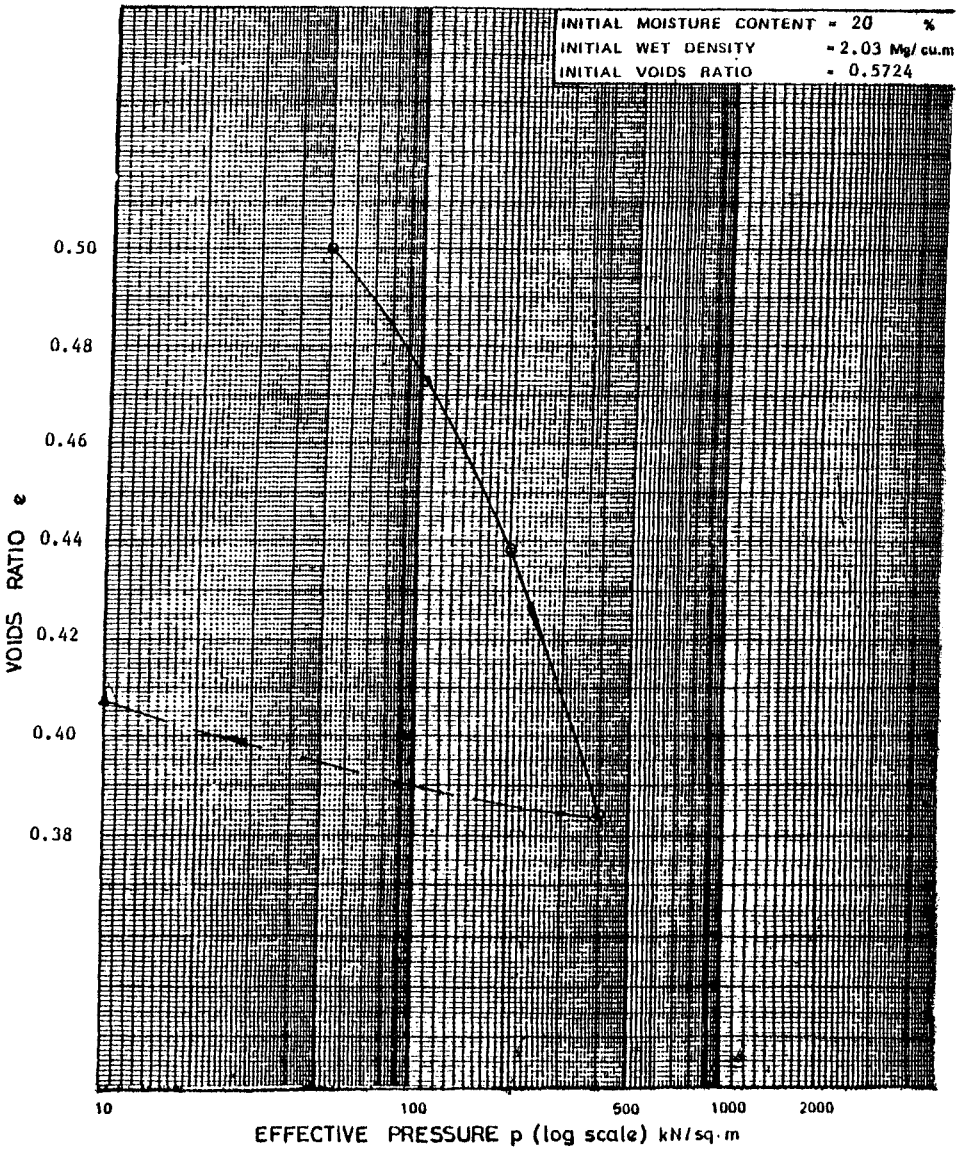
FOUNDATION ENGINEERING SERVICES LTD. FIG. A4

CONSOLIDATION TEST

(e - log p curve)

LOCATION. PROPOSED RURAL ELECTRIFICATION PROJECT AT AWE CITY, NASARAWA STATE
JOB No S10901
DATE OF TEST JUNE, 2000

BOREHOLE No. 1A
SAMPLE No. 5
DEPTH. 2.5m



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MESSRS YACHIYO ENGINEERING CO. LIMITED

PROPOSED PROJECT FOR RURAL ELECTRIFICATION
AT KEANA CITY, NASARAWA STATE,
FEDERAL REPUBLIC OF NIGERIA

REF.: S.10901A/JUNE, 2000

REPORT ON SUBSOIL INVESTIGATION

Carried Out By:-

FOUNDATION ENGINEERING SERVICES LIMITED,
P. O. BOX 2100,
LAGOS.

FE

MESSRS YACHIYO ENGINEERING CO. LIMITED

PROPOSED PROJECT FOR RURAL ELECTRIFICATION

AT KEANA CITY, NASARAWA STATE,

FEDERAL REPUBLIC OF NIGERIA

REPORT ON SUBSOIL INVESTIGATION

1. INTRODUCTION

Further to your letter of award reference YEC-BRG-FDN01 dated 10th May 2000, Foundation Engineering Services Limited carried out a subsoil investigation at Keana city in Keana Local Govt. area of Nasarawa State for the above proposed project. The purpose of the investigation was to provide data on subsoil conditions for foundation design.

The following is our report on the investigation.

2. SCOPE OF INVESTIGATION

2.1 Site Work

The site work was carried out between 7th and 0th June, 2000. The defined scope of site work required comprised 1 No. shell and auger borehole put down and terminated at 6.0m depth on encountering bedrock and the survey of the boring position

to determine the height above Mean Sea Level (MSL) with reference to an established bench mark.

A pilcon Wayfarer 1500 rig with B.S. 5930 shell and auger percussion boring techniques was used to bore through the soil deposits. Both disturbed and undisturbed soil samples were taken and standard penetration tests (SPT) carried out at regular intervals of 1.0m depth as appropriate.

An area map showing Keana city is presented as Figure 1 while a site plan (based on the sketched site layout drawing provided by the client) indicating approximate position of the borehole as selected by yourselves and set out by ourselves is presented as Figure 2.

Borehole log giving details of the strata encountered at the site is presented as Figure 3.

All depths referred to in this report are below ground surface at the time of the investigation and are approximate.

2.2 Laboratory Testing

Laboratory tests relevant to the engineering objectives of the investigation were Scheduled on selected samples retrieved from the borehole. The tests were carried out in general accordance with B.S. 1377; 1990. "Method of Test for Soils for Civil Engineering Purposes"; Parts 1 - 9 unless otherwise stated. The results are presented in tabular and graphical forms in the Appendix.

The following tests were carried out:-

- 4 No. Particle size distribution by wet sieving
- 2 No. Hydrometer Analysis
- 2 No. Atterberg limits determination on material passing 425 micron sieve
- 1 No. Quick Undrained Triaxial Compression Test on 38mm diameter undisturbed sample
- 1 No. Unconfined compression Test
- 4 No. Natural Moisture Content
- 1 No. One-dimensional Oedometer Consolidation Test to determine compressibility characteristics. In calculating the coefficient of consolidation (Cv). "The Square Root of Time Fitting" method was adopted

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1 No. Chemical Analysis of soil samples for hydrogen ion concentration (pH) and soluble sulphate content.

3.0 GEOLOGY OF THE SITE (KEANA CITY, NASARAWA STATE)

The site is generally flat and cultivated. Owing to the recent rainfall it is over grown with long grasses and few scattered trees. The 1:2,000,000 Geological Map of Nigeria compiled by the Geological survey of Nigeria, 1974 Edition, indicates that the site is underlain by black shale and siltstones. The results of the investigation are generally concordant with the overburden soils associated with the description of the site geology.

4.0 SUBSOIL AND GROUNDWATER CONDITIONS

Details of the subsoil strata encountered during boring are given on the borehole log. However, the subsoil sequence may then be generally summarised as follows:-

Depth Below Ground Level (m)		Generalised Strata Description
From	To	
Ground Level	0.5	Soft sandy (c.m.f) silty CLAY With concretions
0.5	1.0	Medium dense clayey silty SAND (c.m.f) with gravel (f)

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1.0	3.0	Very stiff, sandy (c.m.f) silty CLAY with gravel (f)
3.0	6.0 (Borehole Termination)	highly Weathered SILTSTONE

Variations in strata thickness and depths away from the borehole are likely.

Groundwater seepage was not encountered in the borehole. However, indications from local observations are that the groundwater level could vary approximately be between 7.0m and 9.0m depths. Seasonal variations in groundwater level will occur, with the possible development of perched water table within the clayey or indurated layers during or immediately after the wet season.

5.0 LABORATORY TEST RESULTS

Particle size analysis carried out on samples of the overburden clayey deposit gave the range of gravel fraction to be 1% to 23%, sand 32% to 59%, silt 5% to 11% clay 37% to 50% by weight. Detailed results are presented on the summary sheet and graphically on the particle size distribution curves in the Appendix.

The index properties of the clayey deposits were investigated by means of Atterberg limits tests on some samples. The natural moisture content (W) ranged between 12% to 20%. Also liquid limit (wL) varied between 40% to 58%, while the plastic limit (WP) ranged from 15% to 21%. Therefore the plasticity index (IP) was of the order of 25% to 37%. This indicate medium to high plasticity.

The liquidity index (IL) which is equals to the moisture content (W) minus plastic limit (WP) divided by plasticity index (IP) for the various samples tested was computed. A normally consolidated clay has a moisture content (W) approaching the liquid limit with a liquidity index (IL) tending to unity, while an over-consolidated clay has a moisture content around the plastic limit with a liquidity index of approximately zero or negative. The samples considered gave liquidity index values of between -0.24 and -0.20. These indicate the clays are generally over-consolidated.

The shear strength of the cohesive deposits were determined by means of Quick Undrained Triaxial Compression Test and Unconfined Compressive Test on undisturbed samples. The undrained cohesion (Cu) was indicated to be 200 kN/m^2 with the angle of internal friction (Øu) of 5 degrees and unconfined compressive test was

indicated to be 280 kN/m^2. This result indicate stiff to very stiff consistency and are tabulated in the Appendix.

The bulk wet density of the clayey deposits was 2.05 mg/m^3.

Deformation characteristics of the clay deposits were determined in oedometer apparatus. The coefficients of consolidation (Cv) and compressibility (Mv) at various overburden pressure are presented on the summary table, while the graph of voids ratio (e)/log of effective pressure (P) relationship for the sample tested is presented in the Appendix. The result indicates the clay deposits to be of low compressibility.

The aggressiveness of the soil samples to concrete was assessed by the determination of hydrogen ion concentration (pH) and soluble sulphate content of 1 No. sample. The pH value was indicated to be 5.8 indicating slightly acidic conditions, with very small soluble sulphate content (0.004 gr/litre).

From the survey work, carried out at the boring position (Borehole 1).
The following values are tabulated below in Table 1;-

Station	Starting Point and Height above the Mean Sea Level (MSL) (m)	Distance Covered (m)	Height of Boring Station above the Mean Sea Level (MSL) (m)	Height of Temporary Bench Mark (m)
Keana City	Trig. Station H9 700	12.5	389.484	389.346

Table 1

Note: More detailed survey report is presented in the Appendix.

6.0 DISCUSSION

6.1 Design Details

It is understood that it is proposed to install a transformer of about 12 ton (120kN). No further details have been made available to us. However, for the purpose of this report, we have assumed a maximum overall ground loading of 60 kN/m^2.

The following comments and recommendations are based on the borehole log and on the results of the laboratory tests.

6.2 Shallow Foundation

The results of in-situ and laboratory test carried out indicated the presence of a medium dense clayey silty sand within the top 1.5m and very stiff silty clay with decomposed rock to 3.0m depth within which a shallow foundation can be set.

Generally as a guide, it is estimated that the net allowable bearing pressures that may be imposed at different founding depths are as shown in Table 2 below.

These Figures have taken into consideration the relief provided by the overburden assummed to be removed above the founding level.

Founding Depth (m)	Allowable Bearing Pressure (kN/m^2)
1.0	60
1.5	100
2.0	150
3.0	200

Table 2. Estimated Allowable Pressure for shallow Foundation.

However, it is recommended that reinforced concrete strip or pad foundations may be adopted for supporting the proposed structures at this site. The foundations should not be less than 1.0m wide, set on undisturbed virgin stiff silty clay and not shallower than 1.0m depth in order to avoid problems of seasonal moisture variation.

6.3 Settlement

Settlement due to consolidation of clayey strata beneath foundation level will be dependent on the foundation type and width, its founding depth, the bearing pressure imposed and care taken in excavating and preparing the formation level.

Settlement of strip or pad foundations constructed to the standards, loading and depths stated above is estimated to be less than 20mm with differential settlement not exceeding 10mm.

6.4 Foundation Preparation

The base of the foundation excavation must be carefully probed and inspected for soft pockets which, if encountered, must be completely removed and replaced with well compacted relatively dry lean mix concrete.

Immediately after preparation, the foundation level must be protected with blinding layer of concrete as the soil may soften if left exposed or if ingress of water is allowed.

It is our experience that the type of silty clay encountered at this site is very susceptible to softening and disturbance by the ingress of water and by construction processes. It is therefore most important that great care be taken not to disturb

the soil at or below foundation level during excavation and that it must be kept dry at all times.

Backfilling to the sides of the foundation should be placed to ground level as soon as possible following casting of the foundation. Backfilling of excavations around completed foundations should be with suitable material placed in thin layers not exceeding 200mm thickness and compacted to a high standard.

Backfilling of foundations in cohesive deposit such as encountered at this site should be with materials which, when compacted as recommended above, will be less permeable than the surrounding ground. This will prevent seepage through or between the backfill and the original ground and avoid softening of the clay at or below foundation level.

7.0 GENERAL

The subsoil conditions are indicated to be slightly acidic, with negligible concentrations of soluble sulphates. Ordinary Portland cement may be used for burried concrete but a rich, dense mix is recommended.

We strongly recommend that the design and construction of all foundation and earthworks be carried out in accordance with a good engineering practice as embodied in recognised Codes of Practice such as the British Standards Institution's B.S. 8004: 1986, Code of Practice for Foundations and B.S. 6031: 1981, Code of Practice for Earthworks.

We trust you find the contents of this report of assistance and assure you of our best attention at all times.

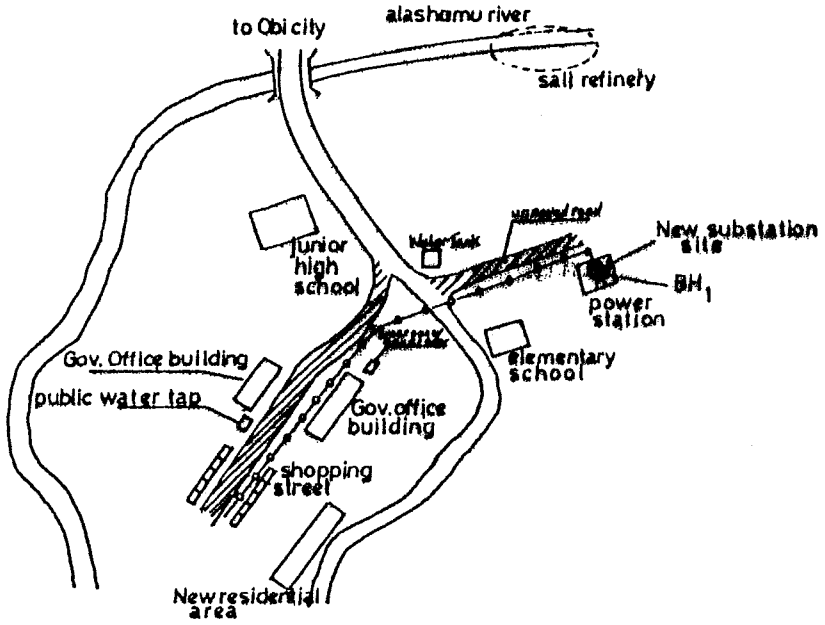
S.C. Aiekola,
Civil Engineer.

Prince Wale Ajayi-Fajomodu,
Managing Director.

FOUNDATION ENGINEERING SERVICES LIMITED,
P. O. BOX 2100,
LAGOS.

REF.:S10901A/JUNE, 2000.

FIG. 2



Proposed Project For Rural Electrification
At Keana City, Nassarawa State.

LOCATION MAP

KEY

● :- Borehole Postion.

(S10901A)

Foundation Engineering Services Limited

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FIG. 3

BOREHOLE LOG

LOCATION : PROPOSED RURAL ELECTRIFICATION PROJECT AT KEANA CITY, NASARAWA STATE

JOB No : S10901A

BOREHOLE No : 1 (KEANA CITY)

BOREHOLE DIA : 0.15m

GROUND LEVEL : 389.484m ABOVE MSL)

DATE (Start) : 8/6/2000

GROUND WATER : NOT ENCOUNTERED

DEPTH (m)	LEGEND	SAMPLE No	DESCRIPTION	BLOWS FOR S.P.T. SPOON FOR 0.30m DRIVE (N) 10 20 30 40 50
0		●1	Soft, red-brown sandy (c.m.f) silty CLAY with concretions (TOPSOIL)	
1		●2 +3	Medium dense, dark brown clayey silty SAND (c.m.f) with siltstone	10
		14		48
2		+5		
		●6	Very stiff, pupple mottled grey and white silty CLAY with pockets of decomposed rock at 3.0m depth	
3		+7		53
		●8		
4		●9		
		●10		
5		●11	Very hard, mottled grey and brown highly weathered siltstones	
		●12		
6		●13		
			Borehole terminated at 6.0m depth	
7				
8				
9				
10				
11				
12				
13				
14				
15				

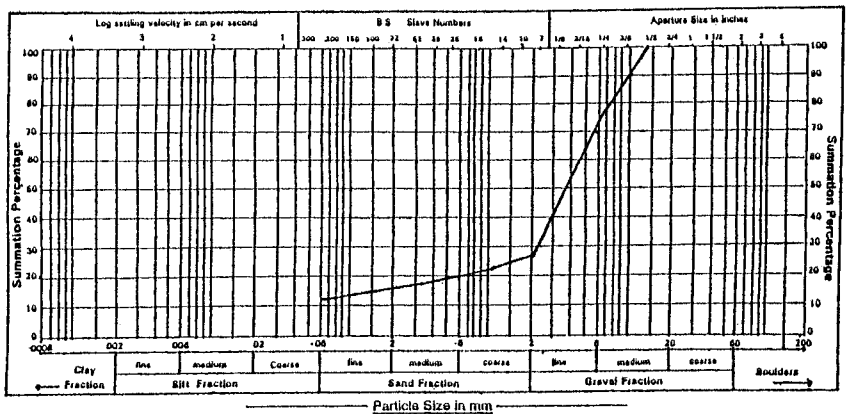
PARTICLE SIZE DISTRIBUTION

CONTRACT: S10901A PROPOSED RURAL ELECTRIFICATION PROJECT AT KEANA CITY, NASARAWA STATE

DATE: JUNE, 2000

BOREHOLE/SAMPLE NO: 1/1 DEPTH: 0.15m

LOSS ON PRETREATMENT: -

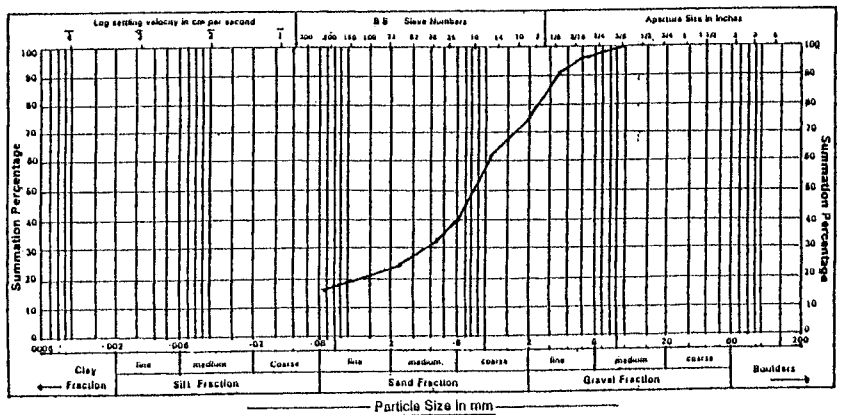


CONTRACT: S10901A PROPOSED RURAL ELECTRIFICATION PROJECT AT KEANA CITY, NASARAWA STATE

DATE: JUNE, 2000

BOREHOLE/SAMPLE NO: 1/3 DEPTH: 1.0m

LOSS ON PRETREATMENT: -



FOUNDATION ENGINEERING SERVICES LTD

Summary of Laboratory Test Results.

LOCATION: PROPOSED RURAL ELECTRIFICATION PROJECT AT KEANA CITY, NASARAWA STATE

CONTRACT No: S10901A

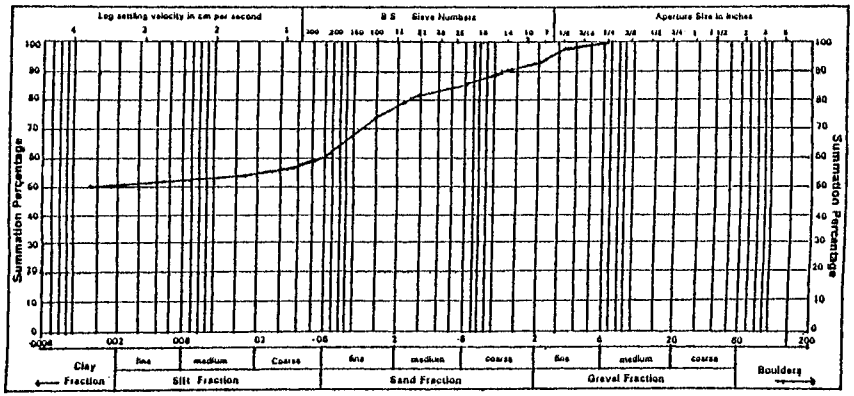
SHEET:- 1 OF 1

BOREHOLE/SAMPLE No.	TYPE	DEPTH m	PARTICLE SIZE DISTRIBUTION % PASSING 2·00 mm	425 µm	63 µm	2 µm	NAT M.C. % dw	ATTERBERG LIMITS LL % dw	PL % dw	PI % dw	γdB Mg/m³	S.G.	QUICK UNDRAINED TRIAXIAL TESTS dia. (mm) type	σ3 kN/m²	Cu kN/m²	φu deg	LAB VANE Su kN/m²	OEDOMETER CONSOLIDATION STRESS RANGE kN/m²	Mv m²/MN	Cv m²/yr	pH	SO3 (s) gr/litre	SO3 (w) ppm	Unconfined Compressive Strength (kN/m²)
1/1	D	0.15	27	19	12		17																	
1/3	D	1.0	76	32	17		15											50–100	0.139	2	5.8	0.004		280
1/4	U	1.5	93	84	61	50	12	58	21	37	2.05			100	200	5		100–200	0.124	3				
														200				200–400	0.104	2				
1/7	D	3.0	99	89	42	37	20	40	15	25														

PARTICLE SIZE DISTRIBUTION

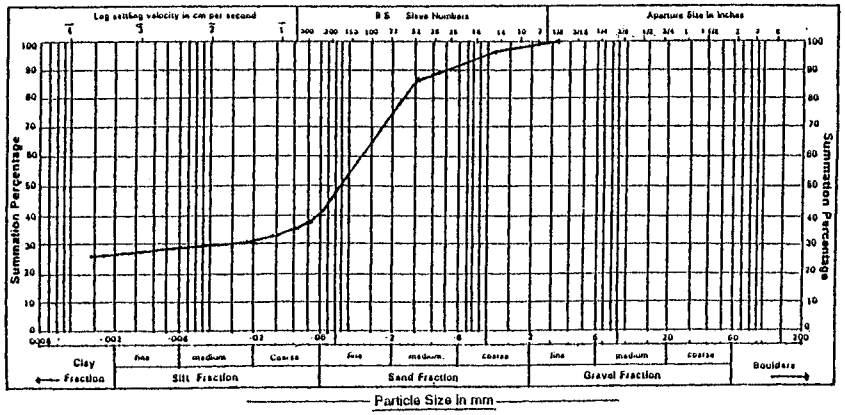
CONTRACT: S10901A PROPOSED RURAL ELECTRIFICATION PROJECT AT KEANA CITY, NASARAWA STATE DATE: JUNE, 2000

BOREHOLE/SAMPLE NO: 1/4 DEPTH: 1.5m LOSS ON PRETREATMENT: -



CONTRACT: S10901A PROPOSED RURAL ELECTRIFICATION PROJECT AT KEANA CITY, NASARAWA STATE DATE: JUNE, 2000

BOREHOLE/SAMPLE NO: 1/7 DEPTH: 3.0m LOSS ON PRETREATMENT: -



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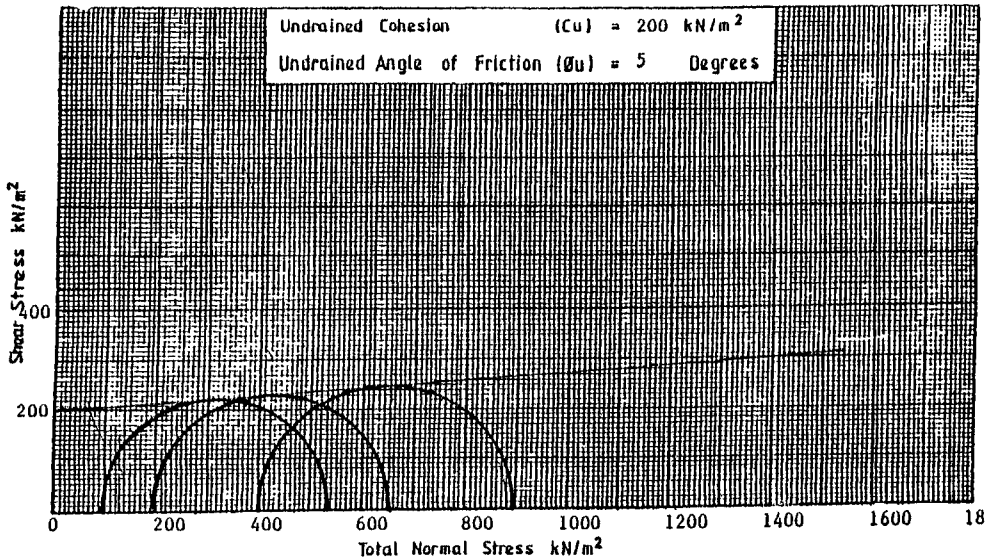
QUICK UNDRAINED TRIAXIAL COMPRESSION TEST

MOHR CIRCLES DIAGRAM

LOCATION: PROPOSED RURAL ELECTRIFICATION PROJECT AT KEANA CITY, NASARAWA STATE BOREHOLE No 1

JOB No S10901A SAMPLE No. 4

DATE OF TEST JUNE, 2000 DEPTH 1.5m



BOREHOLE No. SAMPLE No. DEPTH

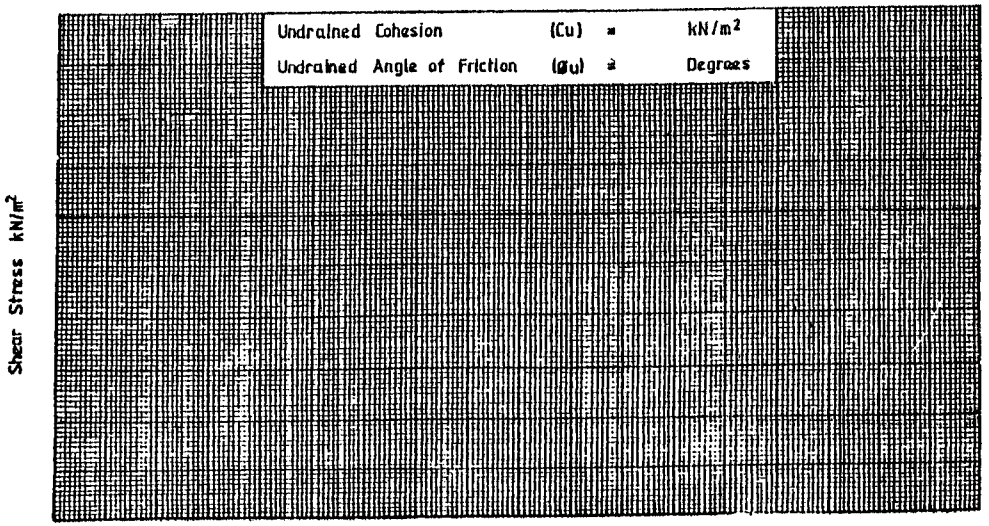


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FIG. A4

CONSOLIDATION TEST

(e - log p curve)

LOCATION: PROPOSED RURAL ELECTRIFICATION PROJECT AT KEANA CITY, NASARAWA STATE

JOB No S10901A

DATE OF TEST JUNE, 2000

BOREHOLE No. 1

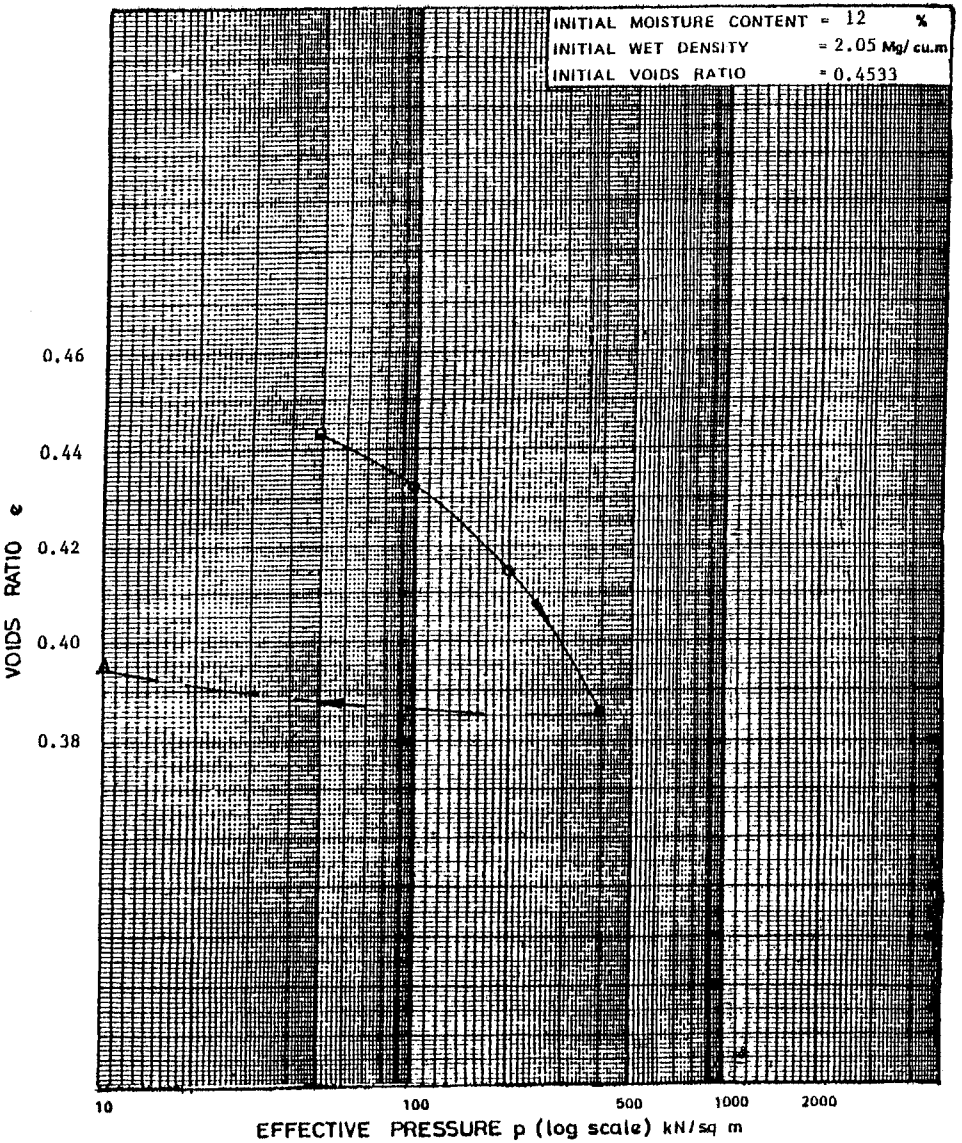
SAMPLE No. 4

DEPTH 1.5m

INITIAL MOISTURE CONTENT = 12 %

INITIAL WET DENSITY = 2.05 Mg/cu.m

INITIAL VOIDS RATIO = 0.4533



FE
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SABO, YABA,
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MESSRS YACHIYO ENGINEERING CO. LIMITED

PROPOSED PROJECT FOR RURAL ELECTRIFICATION
AT BOGORO CITY, BAUCHI STATE,
FEDERAL REPUBLIC OF NIGERIA

REF.: S.10902/JUNE, 2000

REPORT ON SUBSOIL INVESTIGATION

Carried Out By:-

FOUNDATION ENGINEERING SERVICES LIMITED,
P. O. BOX 2100,
LAGOS.

FE

MESSRS YACHIYO ENGINEERING LIMITED

PROPOSED PROJECT FOR RURAL ELECTRIFICATION

AT BOGORO CITY, BAUCHI STATE,

FEDERAL REPUBLIC OF NIGERIA

REPORT ON SUBSOIL INVESTIGATION

1. INTRODUCTION

Further to your letter of award reference YEC-BRG-FDNO1 dated 18th May 2000, Foundation Engineering Services Limited carried out a subsoil investigation at Bogoro city in Bogoro Local Govt. area of Bauchi State for the above proposed project. The purpose of the investigation was to provide data on subsoil conditions for foundation design.

The following is our report on the investigation.

2. SCOPE OF INVESTIGATION

2.1 Site Work

The site work was carried out on the 5th and 6th June, 2000. The defined scope of site work required comprised 1 No. shell and auger borehole terminated at 1.5m depth on encountering bedrock and the survey of the boring position

to determine the height above Mean Sea Level (MSL) with reference to an established bench mark.

A pilcon Wayfarer 1500 rig with B.S. 5930 shell and auger percussion boring techniques was used to bore through the soil deposits. Both disturbed and undisturbed soil samples were taken and standard penetration tests (SPT) carried out at regular intervals of 1.0m depth as appropriate.

An area map showing Bogoro city is presented as Figure 1 while a site plan (based on the sketched site layout drawing provided by the client) indicating approximate position of the borehole as selected by yourselves and set out by ourselves is presented as Figure 2.

Borehole log giving details of the strata encountered at the site is presented as Figure 3.

All depths referred to in this report are below ground surface at the time of the investigation and are approximate.

2.2 Laboratory Testing

Laboratory tests relevant to the engineering objectives of the investigation were Scheduled on selected samples retrieved from the borehole. The tests were carried out in general accordance with B.S. 1377; 1990. "Method of Test for Soils for Civil Engineering Purposes"; Parts 1 - 9 unless otherwise stated. The results are presented in tabular and graphical forms in the Appendix.

The following tests were carried out:-

2 No.	Particle size distribution by wet sieving
1 No.	Hydrometer Analysis
1 No.	Atterberg limits determination on material passing 425 micron sieve
1 No.	Chemical Analysis of soil samples for hydrogen ion concentration (pH) and soluble sulphate content

3.0 GEOLOGY OF THE SITE

The location investigated indicated to be cultivated farm land with few trees scattered within with some rock outcrops. According to 1:2,000,000 Map of the Geological Survey of Nigeria, the area is underlain with older granite of the pre-combrian to upper combrian period. The rocks are overlain by overburden of variable thickness comprising zone of sand layer and decomposed

FE

rock. The results of the investigation are generally concordant with the overburden soils expected from the above description of the site geology.

4.0 SUBSOIL AND GROUNDWATER CONDITIONS

Details of the subsoil strata encountered during boring are given on the borehole log. However, the subsoil sequence may then be generally summarised as follows:-

Depth Below Ground Level (m)		Generalised Strata Description
From	To	
Ground Level	0.4	Stiff SAND (cmf)
0.4	1.0	Very stiff sandy (cmf) silty micaceous CLAY, with gravel (f) (Decomposed rock)
1.0	1.5 (Borehole Termination)	Fragments of granitic rock

*Variations in strata thickness and depths away from the borehole are likely.

Groundwater seepage was not encountered in the borehole during the period of investigation. However, seasonal variations in

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groundwater level may occur with possible development of perched watertables within the clayey or indurated layers during or immediately after the wet season.

5.0 LABORATORY TEST RESULTS

Particle size analysis carried out on 2 No. samples of the sand and sandy clay deposit gave the gravel fraction to be 23% and 37%, sand 49% and 50%, silt and clay to be 21% by weight. Detailed results are presented on the summary sheet and graphically on the particle size distribution curves in the Appendix.

The index properties of the clayey deposit were investigated by means of Atterberg Limits tests on a samples. The natural moisture content (W) was 12%, liquid limit (WL) was 38% while the plastic limit (WP) was 15%. Therefore the plasticity index (IP) was 23%. This indicate medium plasticity.

The liquidity index (IL) which is equals to the moisture content (W) minus plastic limit (WP) divided by plasticity index (IP), for the various samples tested was computed. A normally consolidated clay has a moisture content (W) approaching the liquid limit with a Liquidity Index (IL) tending to unity, while an over consolidated clay has a moisture content around the

plastic limit with a liquidity index of approximately zero or negative. The sample considered gave liquidity index value of -0.130. This indicates that the clay is over- consolidated.

The aggressiveness of the soil sample to concrete was assessed by the determination of hydrogen ion concentration (pH) and soluble sulphate content of 1 No. sample. The pH value was indicated to be 6.0 indicating slightly acidic conditions, with very small soluble sulphate content (0.004 gr./litre).

From the survey work, carried out at the boring position (Borehole 1).

The following values are tabulated below in Table 1:-

Station	Starting Point and Height above the Mean Sea Level (MSL) (m)	Distance Covered (kN)	Height of Boring Station above The Mean Sea Level (MSL) (m)	Height of Temporary Bench Mark (m)
Bogoro City	Trig. Station Xk 581 875.386m	10.3	686.245	TBM1 = 686.931 TBM2 = 686.566

Note: More detailed survey report is presented in the Appendix.

6.0 FOUNDATION DISCUSSION

6.1 Design Details

It is understood that it is proposed to install a transformer of about 12 ton (120 kN). No further details have been made available to us. However, for the purpose of this report, we have assumed a maximum overall ground loading of 60 kN/m^2.

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The following comments and recommendations are based on the borehole log and on the results of the laboratory tests.

6.2 Shallow Foundation

The results of in-situ and laboratory test carried out revealed the presence of a medium silty sand within the top 0.4m depth and micaceous silty clay (decomposed rock) to 1.0m depth and sound granitic rock fragments to 1.5m depth.

It is therefore recommended that the foundation should be keyed to the bedrock. Prior to emplacement of foundations on bedrock, the foundation level must be carefully inspected for cracks or fractures, soft or loose heavily weathered material and joint infillings which, if encountered, must be completely removed and backfilled with well compacted relatively dry concrete.

The foundation should be then be keyed into sound rock ensuring that the foundation surface is level. It is essential that the excavation is carefully carried out to ensure that the ground at or below the foundation level is not adversely affected by the excavation techniques used, as this may lead to reduced bearing capacity and increased settlement. For excavation in hard material and in sound rock in particular, we recommend that the advice of a specialist in this field be sought.

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Settlement of structures founded on sound rock are negligible ensuring a high construction standard.

Immediately after preparation, the foundation level must be protected with blinding layer of concrete as the soil/rock may soften if left exposed or if ingress of water is allowed.

7.0 GENERAL

The subsoil conditions are indicated to be slightly acidic, with negligible concentrations of soluble sulphates. Ordinary Portland cement may be used for buried concrete but a rich, dense mix is recommended.

Backfilling to the sides of the foundation should be placed to ground level as soon as possible following casting of the foundation. Backfilling of excavations around completed foundations should be with suitable material placed in thin layers not exceeding 200mm thickness and compacted to a high standard.

Backfilling of foundations in cohesive deposit such as encountered at this site should be with materials which, when compacted as recommended above, will be less permeable than the surrounding ground. This will prevent seepage through or between

FE

the backfill and the original gound and avoid softening of the clay at or below foundation level.

We strongly recommend that the design and construction of all foundation and earthworks be carried out in accordance with a good engineering practice as embodied in recognised Codes of Practice such as the British Standards Institution's B.S. 8004: 1986, Code of Practice for Foundations and B.S. 6031: 1981, Code of Practice for Earthworks.

We trust you find the contents of this report of assistance and assure you of our best attention at all times.

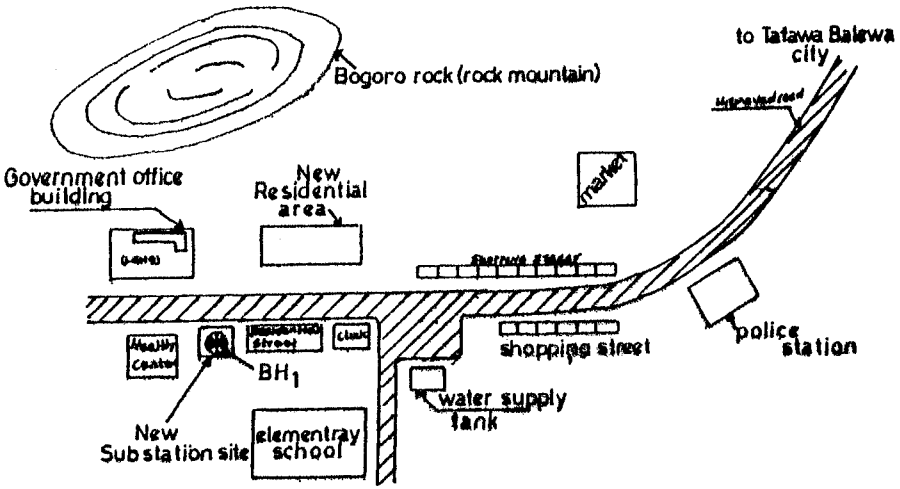
Philip C. Nwamu,
Chief Geologist.

Prince Wale Ajayi-Fajomodu,
Managing Director.

FOUNDATION ENGINEERING SERVICES LIMITED,
P. O. BOX 2100,
LAGOS.

REF.:S10902/JUNE, 2000.

FIG 2



Proposed Project For Rural Electrification
At Borogo City, Bauchi State.

LOCATION MAP
KEY

● :- Borehole Postion.

(S10902) Foundation Engineering Services Limited

FOUNDATION ENGINEERING SERVICES LTD

FIG. 3

BOREHOLE LOG

LOCATION : PROPOSED RURAL ELECTRIFICATION PROJECT AT BOGORO, BAUCHI STATE
JOB No : S10902
BOREHOLE DIA : 0.20m
DATE (Start) : 5/6/2000

BOREHOLE No : 1 (BOGORO)
GROUND LEVEL : 686.245m (ABOVE MSL)
GROUND WATER : DRY

DEPTH (m)	LEGEND	SAMPLE No	DESCRIPTION	BLOWS FOR S.P.T. SPOON FOR 0.30m DRIVE (N) 10 20 30 40 50
0		•1	Grey silty SAND (cmf) with gravel (f) TOPSOIL	
		•2	Very stiff grey sandy (cmf)silty CLAY: slightly micaceous with gravel (f) (Decomposed Rock)	24
1		+3	Light grey fragments of granitic Rock	
		•4	Borehole terminated at 1.5m depth	
2				
3			Note: Chiselled for 1hr. from 1.25m to 1.5m depth	
4				
5				
6				
7				

FOUNDATION ENGINEERING SERVICES LTD

Summary of Laboratory Test Results.

LOCATION: PROPOSED RURAL ELECTRIFICATION PROJECT AT BOGORO CITY, BAUCHI STATE

CONTRACT No: S10902

SHEET:- 1 OF 1

BOREHOLE/ SAMPLE No.	TYPE	DEPTH m	PARTICLE SIZE DISTRIBUTION % PASSING 2·00 mm	425 µm	63 µm	2 µm	NAT M.C. % dw	ATTERBERG LIMITS LL % dw	PL % dw	PI % dw	γB Mg/m³	SG	QUICK UNDRAINED TRIAXIAL TESTS dia (mm) type	σ3 kN/m²	Cu kN/m²	φu deg	LAB VANE Su kN/m²	OEDOMETER CONSOLIDATION STRESS RANGE kN/m²	MV m²/MN	CV m²/yr	pH	SO3 (s) gr/litre	SO3 (w) pp 10⁵	COMMENTS OTHER TESTS
1/1	D	0.15	63	28	14		13																	
1/2	D	0.75	77	47	27	21	12	38	15	23											5.9	0.004		

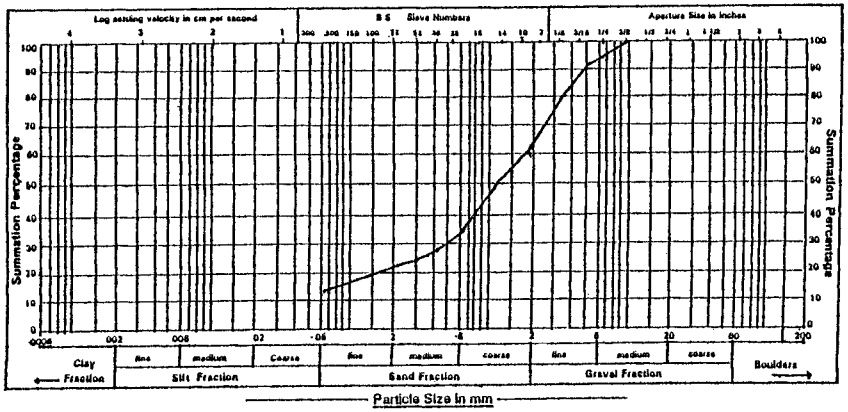
PARTICLE SIZE DISTRIBUTION

CONTRACT: S10902 PROPOSED RURAL ELECTRIFICATION PROJECT AT BOGORO, BAUCHI STATE

DATE: JUNE, 2000

BOREHOLE/SAMPLE NO: 1/1 DEPTH: 0.15m

LOSS ON PRETREATMENT: -



CONTRACT: S10902 PROPOSED RURAL ELECTRIFICATION PROJECT AT BOGORO, BAUCHI STATE

DATE: JUNE, 2000

BOREHOLE/SAMPLE NO: 1/2 DEPTH: 0.75m

LOSS ON PRETREATMENT: -