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MINISTRY OF WORKS AND TRANSPORT

CENTRAL MATERIALS LABORATORY, KIREKA

GEOTECHNICAL INVESTIGATIONS REPORT AT THE SITE PROPOSED FOR CONSTRUCTION OF OFFICE BLOCK AT PLOTS 2-12, SIR APOLLO KAGGWA ROAD, KAMPALA

CHIEF MATERIALS ENGINEER
JULY 2018

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LIST OF SYMBOLS

BH	-	Borehole
BS	-	British Standard
C	-	Cohesion
CH	-	Sandy fat clay
CL^-	-	Chlorides
CL	-	Sandy lean clay
D	-	Position of disturbed samples
EN	-	Euro Standard (NORME EUROPÉENE)
I_c	-	Consistency Index
kPa	-	kiloPascal
LL	-	Liquid Limit
m	-	Meters
MH	-	Elastic silt
MoFPED	-	Ministry of Finance, Planning and Economic Development
N -value	-	Field blow count based on standard penetration test by free falling hammer (blows/450mm)
N_c, N_γ,N_q	-	Bearing capacity factors
NMC	-	Natural Moisture Content
PI	-	Plasticity Index
PL	-	Plastic Limit
q_{all}	-	Allowable bearing capacity
q_{ult}	-	Ultimate bearing capacity
SC	-	Clayey sand
SO_4^{2-}	-	Sulphates
SPT	-	Standard Penetration Test
U – 100	-	Position of undisturbed samples
USCS	-	Unified Soil Classification System
Φ	-	Angle of shearing resistance

CHAPTER ONE: INTRODUCTION

1.1 Background

At the request of the **MINISTRY OF FINANCE, PLANNING AND ECONOMIC DEVELOPMET (MoFPED);** Central Materials Laboratory-Kireka conducted geotechnical investigation at the site proposed for the construction of an office block the month of July 2018. The field investigations and testing were aimed at evaluating the in-situ soils properties and obtaining suitable geotechnical data for appropriate design of foundations for the proposed structures to be constructed at the site. These were supplemented by laboratory tests conducted on the recovered soil samples.

1.2 Purpose and Scope of Work

The scope of the investigations comprised:

i. Drilling three (3No.) boreholes to refusal or to a maximum depth of 10.5m where possible in normal soils;
ii. Conducting Standard Penetration Tests (SPTs) at 1.5m intervals up to 10.5m depth where possible in all the boreholes;
iii. Obtaining at least one undisturbed samples at suitable depths where possible from the bore holes drilled;
iv. Determining the level of groundwater in the boreholes where encountered;
v. Carrying out laboratory tests on retrieved samples; and
vi. Compiling a geotechnical report.

This report forms the key output of the exercise and describes the field and laboratory activities carried out as well as the findings arising there from. No reliance is to be placed on the content of this report for any use other than that for which it was intended. The report is prepared for the exclusive use for purposes of geotechnical design of the proposed works.

This report has been prepared in the light of legislation and best practice currently in the construction industry.

The Ministry of Finance, Planning and Economic Development**;** authorized Central Materials Laboratory to conduct the geotechnical investigation as part of the design and in accordance with the requirements by the local authority for the design of the foundation of the building.

1.3 Structure of the Report

The report has been structured as follows:

Chapter 1: Introduction

Chapter 2: Site Description and Seismology

Chapter 3: Methodology

Chapter 4: Findings

Chapter 5: Evaluation of Bearing Capacity Values

Chapter 6: Conclusion and Recommendation

Bibliography

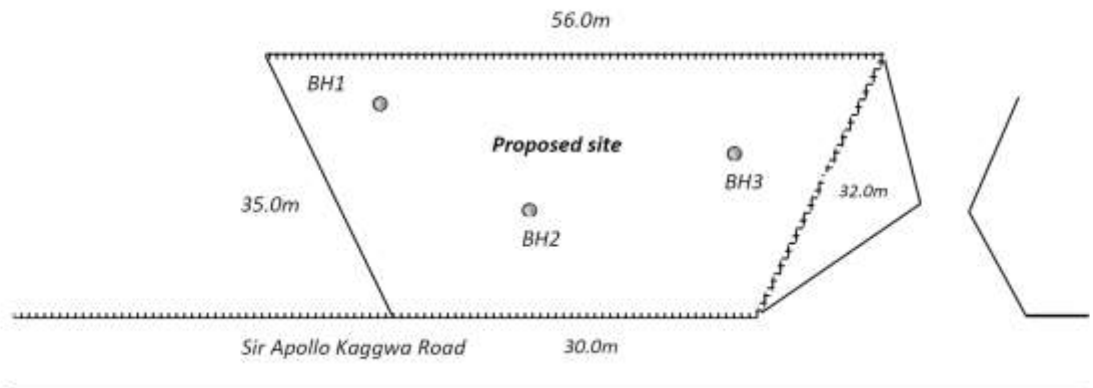
Appendices:

1. Sketch Map of the Site Showing Borehole Locations
2. Boreholes Logs
3. Soil Index Properties
4. Bearing Capacities of Soils due to SPT – N values
5. Bearing Capacities of Soils due to Shear Strength
6. Chemical Test Results on Soils Samples

CHAPTER TWO: SITE LOCATION AND SEISMOLOGY

2.1 Site Location

The proposed development will be located at Plots 2-12, Sir Apollo Kaggwa Road, Kampala. A sketch map of the site is presented below and in Appendix 1.



2.2 Seismology

The site lies within zone 3 of the seismic zoning of Uganda, implying there is low risk of earthquake occurrence at the site. (Seismic Code of Practice for Structural designs; Uganda National Bureau of Standards, First Edition: June 2003).

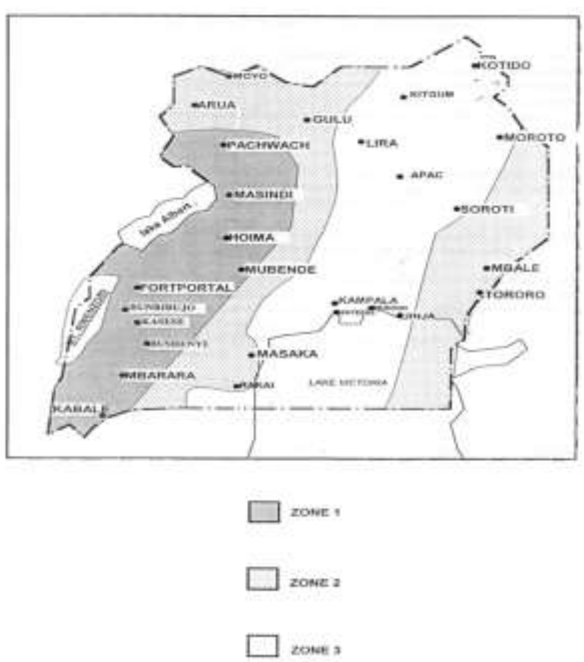


Figure 1: Seismic zoning of Uganda

CHAPTER THREE: METHODOLOGY

3.1 Field Work

The field exploratory activities were conducted in accordance with BS EN 1997-2:2007, "Part 2: Ground Investigations and Testing" as briefly described below. The key activities comprised site reconnaissance surveys, identification of boreholes positions, rotary boring, conducting standard penetration tests, sampling and description of soil properties. The boreholes positions were accurately established on the ground through setting out and pegging. The sketch map of the site showing borehole locations is shown in Appendix 1.

3.1.1 Rotary Boring, Standard Penetration Tests and Soils Sampling

The 3No. Boreholes were drilled using a rotary auger drilling rig. The drilling tool, which is attached to the lower end of a string of drill auger comprised of a drilling bit attached at the end. The drilling bit was fixed to the lower end of the auger which in turn was carried by the drilling head.

Standard penetration tests (SPT) were conducted in each borehole by driving a split spoon sampler (tube) into the holes using a hammer mechanism. The sampler comprised a split tube with a driving head and a solid cone point (head). The head of the tube was connected to a 63.5kg hammer using a series of drill rods. The tube was driven into the ground by the process of the hammer dropping through a distance of 760mm (hammer blow). At every test depth (test zone) counts of the number of blows required to drive the tube into the soils (penetration depth) through a total distance of 450mm were made after every interval of 150mm penetration. Thereafter, the SPT N-values were taken as the number of blows required to achieve a penetration from 150mm to 450mm i.e. within the subsequent 300mm.

The N-values were then used to estimate the consistency, density, and strength (bearing capacity) of the in-situ sub soils using Terzaghi's empirical relationships. Results are presented in Appendix 2.

3.1.2 Ground Water Table

The boreholes were left open in order to monitor and observe the occurrence of ground water. The depth of ground water was measured using an electric water level indicator.

3.2 Laboratory Testing (To be conducted)

Laboratory tests were conducted in accordance with the standard test methods as briefly outlined in the following sections below:

Name of Test	Standard Test Method	Sample Status
Moisture content	BS 1377: Part 2: 1990	Undisturbed
Particle size distribution	BS 1377: Part 2: 1990	Disturbed
Liquid Limit	BS 1377: Part 2: 1990	Disturbed
Plastic Limit	BS 1377: Part 2: 1990	Disturbed
Plasticity Index	BS 1377: Part 2: 1990	Disturbed
Shear box test	BS 1377: Part 7: 1990	Undisturbed
Chemical tests	BS 1377: Part 3: 1990	Disturbed

3.2.1 Natural Moisture Content

Representative specimens were obtained from each of the samples and their net weights taken. The specimens were oven dried at temperatures between 105^{o}C and 110^{o}C for 24 hours and their dry weights were established. The ratios of moisture loss (wet mass – dry mass) to the mass of the dried soil expressed as a percentage were recorded as the moisture contents of the respective specimens. Results are presented in Appendix 3.

3.2.2 Sieve Analysis

Representative specimens were taken from the samples and oven dried at temperatures between 105^{o} and 110^{o}C for 24 hours. The dried soil specimens were washed through a 0.075mm BS test sieve in accordance with the test method. The retained fractions were again oven-dried for 24 hours at the same temperature and then sieved through a nest of BS test sieves in a descending order of aperture sizes, using a mechanical sieve shaker. The fractions retained on each sieve were weighed and the proportions of the original sample passing given sieves were determined. Results are presented in Appendix 3.

3.2.3 Liquid Limit (LL)

A BS cone penetrometer fitted with an automatic timing device that ensures 5 second penetration under an 80g load was used. An oven-dried representative specimen from each sample was pounded and sieved through a 0.425 mm BS test sieve, after which 200g of each specimen passing the 0.425 mm BS test sieve was mixed thoroughly with distilled water and the water was allowed to permeate it overnight in an air tight container. The respective specimens were then remixed the following day with sufficient water to achieve two penetrations in the range between 15mm and 25mm. The moisture content for each of the pastes was recorded. A moisture content penetration curve was drawn from which the moisture content at 20mm penetration was taken as the liquid limit. Details of the results are presented in Appendix 3.

3.2.4 Plastic Limit (PL)

The specimens used for the tests were prepared in the same manner as those for the liquid limit tests. The test consisted of rolling a ball of soils paste from each sample between the hands and then into threads between the palm and a glass plate. The plastic limits for the respective specimens were recorded as the moisture contents at which the threads develop transverse cracks when they were about 3mm diameter. Details of the results are presented in Appendix 3.

3.2.5 Plasticity Index (PI)

The plasticity index is the numerical difference between the LL and PL i.e. (PI = LL – PL). Details of the results are presented in Appendix 3.

3.2.6 Consistency Index (I_c)

The consistency index is defined as the ratio of "the liquid limit (LL) minus the natural moisture content (NMC)" to plasticity index" i.e. $I_c = (LL – NMC)/PI$.

3.2.7 Shear Strength Test

The first specimen was given a fixed normal stress close to the respective overburden pressure and was sheared along its horizontal plane through its mid-depth to failure. The process was repeated for the other specimens but this time with the fixed normal stresses being successively increased to higher values. The failure points were noted. A plot was made between the normal stress as the abscissa and the shear stress as the ordinate. The respective slopes of the graphs were taken as the angles of internal friction Φ, and the intercepts as the cohesion values C. Details of the plotted graphs and the test results are as shown in Appendix 5.

3.2.8 Chemical Constituents and pH

3.2.8.1 Sulphate Content

Water extract of acid soluble Sulphate in each of the soil specimens was first prepared. The respective samples were filtered and a standard solution of barium chloride added. The precipitated Barium Sulphate was collected, ignited and weighed. The Sulphate content in each specimen was then calculated from the mass of the water used in the analysis and the mass of Barium Sulphate precipitated. Details of the test results are presented in Appendix 6.

3.2.8.2 Chloride Content

Representative samples from the respective specimens passing 0.150mm BS test sieve were each poured in a beaker of 500ml volume, and 50ml of distilled water was added to it followed by 15ml of concentrated nitric acid. In each case the mixture was then heated to near boiling point, cooled and filtered through coarse graded filter paper. The residue was washed with distilled water and all the filtrate collected. Silver nitrate was then added to the filtrate from a burette until all the chlorides were precipitated. Titration was done with standard Potassium Thiocyanate using ferric alum as an indicator. 3,5-5 Trimethylhexan-l-ol was used to coagulate the precipitate. Details of the results are presented in Appendix 6.

3.2.8.3 pH

The Electrometric method of pH determination was adopted. For every specimen, 10g of soils sample was mixed with distilled water in 100ml beaker and stirred for a few minutes, covered with a cover glass and allowed to stand for 8hours. The pH meter was initially calibrated using a standard buffer solution, and then the electrode was washed with distilled water and immersed in the dissolved soils sample. The corresponding readings were taken after every brief stirring between each reading. Details of the results are presented in Appendix 6.

CHAPTER FOUR: FINDINGS

4.1 Field Findings

4.1.1 Visual Observations

From visual inspection of the samples, the in-situ soils in all boreholes were found to comprise of clayey sand (SC) and silty sands (SM).

The photo plates below show some of the processes and findings from the field work.

Figure 1: 1.0 – 4.0: Conducting drilling operations

Figure 2:5.0 – 8.0: Soils samples retrieved from different boreholes

4.1.2 Ground Water Table

At this site no ground water was encountered. This implies that the bearing capacity of the sub soils will not be influenced in any way.

4.1.3 Standard Penetration Tests (SPT)

On the basis of the SPT's conducted in the boreholes, the soil profiles have been categorized into different soil types as described in Table 1.0.

Table 1: SPT values of soil strata in the boreholes

Label	Depth (m)	SPT-N Values	Consistency	Description	Origin
BH1	1.5	16	Medium dense	Clayey sand	Residual
	3.0	20	Medium dense	Clayey sand	Residual
	4.5	52	Very dense	Silty sand	Residual
	6.0	60	Very dense	Silty sand	Residual
	7.5	71	Very dense	Silty sand	Residual
	9.0	80	Very dense	Silty sand	Residual
	10.5	85	Very dense	Silty sand	Residual
BH2	1.5	14	Medium dense	Clayey sand	Residual
	3.0	14	Medium dense	Clayey sand	Residual
	4.5	56	Very dense	Silty sand	Residual
	6.0	64	Very dense	Silty sand	Residual
	7.5	80	Very dense	Silty sand	Residual
	9.0	78	Very dense	Silty sand	Residual
	10.5	92	Very dense	Silty sand	Residual
BH3	1.5	19	Medium dense	Clayey sand	Residual
	3.0	21	Medium dense	Clayey sand	Residual
	4.5	58	Very dense	Silty sand	Residual
	6.0	69	Very dense	Silty sand	Residual
	7.5	69	Very dense	Silty sand	Residual
	9.0	77	Very dense	Silty sand	Residual
	10.5	80	Very dense	Silty sand	Residual

Generally, the profile comprised underlying residual materials from 0.0m to 10.5m and were of medium dense and very dense consistency.

4.2 Laboratory Findings (to be added)

4.2.1 Classification

Table 2.0 presents a summary of the soils index properties with mainly soils exhibiting a mixture of low, medium and high plasticity for BH1 and BH; and predominantly high plasticity for BH3 residual materials. (See details in Appendix 3).

Table 2: Soil Index Properties for the Soil Samples – to be added

Label	Depth (m)	Grain size/percentage passing		Soil Index Properties					USCS
		5 – 0.075mm	<0.075mm	LL (%)	PL (%)	PI (%)	NMC (%)	I_c	
BH1	1.5								
	3.0								
	4.5								
	6.0								
	7.5								
	9.0								
	10.5								
BH2	1.5								
	3.0								
	4.5								
	6.0								
	7.5								
	9.0								
	10.5								

Table 2: Soil Index Properties for the Soil Samples (cont'd) – to be added

Label	Depth (m)	Grain size/percentage passing		Soil Index Properties					USCS
		5 – 0.075mm	<0.075mm	LL (%)	PL (%)	PI (%)	NMC (%)	I_c	
BH1	1.5								
	3.0								
	4.5								
	6.0								
	7.5								
	9.0								
	10.5								
BH2	1.5								
	3.0								
	4.5								
	6.0								
	7.5								
	9.0								
	10.5								

The soils were found to predominantly consist of clay-sand mixtures of low to high plasticity. The consistency index was computed from the formula: $I_c = (LL - NMC)/PI$. From the computation above therefore, the consistency index of the soils was generally more than unity implying that the natural moisture content are less than their plastic limits. Such soils exhibit semi-plastic consistencies within the moisture regime.

4.2.2 Shear Strength Parameters

Results from the shear box tests in Appendix 5 are summarized in Table 3.0 below as follows:

Table 3.0: Shear Strength Parameters – to be added

Label	Depth (m)	Cohesion C (kPa)	Angle of internal friction Φ(degrees)
BH2	6.0		
BH3	6.0		

4.2.3 Chemical Constituents and pH – to be added

The chemical properties of the soils samples recovered from the boreholes are as summarized in table 4.0 below; see details in appendix 5.

Table 4.0: Summary of the chemical test results – to be added

Location/label	Depth (m)	pH	Cl^- (%)	$SO_4^=$ (%)
BH1	1.5			
	3.0			
	4.5			
	6.0			
	7.5			
	9.0			
	10.5			
BH2	1.5			
	3.0			
	4.5			
	6.0			
	7.5			
	9.0			
	10.5			
BH3	1.5			
	3.0			
	4.5			
	6.0			
	7.5			
	9.0			
	10.5			
Permissible Limits		**6.0 – 9.0**	**0.4 Max.**	**0.2 Max**
		BS 8110: Part 1: 1985: Sub section 6.2.3.3	**BS 8110: Part 1: 1985: Sub section 6, Table 6.4**	**BS 8110: Part 1: 1985: Sub section 6, Table 6.1**

Sulphates and chlorides in the soils strata at the site were found to be in negligible quantities. This implies that no special cements or foundation treatment shall be required to avert any chemical attack from the soils.

CHAPTER FIVE: BEARING CAPACITY EVALUATION

5.1 The Soils Bearing Capacity Values Based on SPT-N values

The maximum pressures the soils are capable of resisting were estimated from the field N-values based on empirical relations and the following assumptions:

i. The Peck et al (1967) relationship between N-values and unconfined compressive strength is valid for cohesive soils; and

ii. The maximum allowable settlement in non-cohesive soils is 25mm.

The corresponding bearing capacity values are as summarized in Table 5.0 below; see details in appendix 4.

Table 5.0: Evaluated Bearing Capacities of Sub Soils Based on SPT N – values

Label	Depth (m)	SPT-N Values	Ultimate Bearing Capacity (kPa)	Allowable Bearing Capacity(kPa)
BH1	1.5	16	465	155
	3.0	20	581	194
	4.5	52	1510	503
	6.0	60	1742	581
	7.5	71	2061	687
	9.0	80	2323	774
	10.5	85	2468	823
BH2	1.5	14	406	135
	3.0	14	406	135
	4.5	56	1626	542
	6.0	64	1858	619
	7.5	80	2323	774
	9.0	78	2265	755
	10.5	92	2671	890
BH3	1.5	19	552	184
	3.0	21	610	203
	4.5	58	1684	561
	6.0	69	2003	668
	7.5	69	2003	668
	9.0	77	2235	745
	10.5	80	2323	774

The bearing capacities based on SPT N-Values ranged from 135kPa to 890kPa between the depths of 1.5m to 10.5m in all the boreholes.

5.2 The Soils Bearing Capacity Values Based on Shear Box Test – to be added

The shear strength parameters indicate mixed c-φ soils which derive their bearing capacity from both cohesion and internal friction as summarized in Tables 6.0 and 7.0 below. See details in Appendix 5.

Table 6.0: Bearing capacity values due to shear strength (general shear) – to be added

Label	Depth (m)	Parameters				
		Cohesion C (kPa)	Angle of internal friction Φ(degrees)	Ultimate Bearing Capacity, q_{ult} (kPa)	Safety factor	Allowable Bearing Capacity, q_{all} (kPa)
BH2	6.0					
BH2	6.0					

Table 7.0: Bearing capacity values due to shear strength (local shear) – to be added

Label	Depth (m)	Parameters				
		MODIFIED COHESION C' (KPa)	MODIFIED ANGLE OF FRICTION Φ' (Degrees)	Ultimate Bearing Capacity, q_{ult} (kPa)	Safety factor	Allowable Bearing Capacity, q_{all} (kPa)
BH2	6.0					
BH3	6.0					

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

i. The site was investigated by drilling three boreholes to refusal depth or a maximum depth of 10.5m in medium dense and very dense formations and Standard Penetration Tests (SPT) were conducted at 1.5m depth intervals in all the boreholes;

ii. The site lies within the seismic zone 3 of Uganda, which has low risk of earthquake occurrence;

iii. The in-situ soils at the site were found to comprise clayey sand (SC) and silty sand (SM);

iv. Water table was not encountered in all of the boreholes explored;

v. The consistency index of the soils was generally more than unity; implying that the natural moisture content are less than their plastic limits. Such soils exhibit semi-plastic consistencies within the moisture regime;

vi. The SPT-N values in the residual material increases greatly with the depth below the existing ground level. Generally, the soil consistency was found to be sand-silt mixtures;

vii. The allowable bearing capacity values determined from SPT - N values ranged from 135kPa to 890kPa between 1.5m to 10.5 m;

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