SOIL INVESTIGATION AND GEOTECHNICAL STUDY REPORT FOR MARIDI COUNTY STRUCTURES

LADDER FOR ENGINEERING AND GENERAL TRADING CO.LTD

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EXECUTIVE SUMMARY

This Executive Summary is provided as a brief overview of our geotechnical engineering evaluation for the project and is not intended to replace more detailed information contained elsewhere in this report. As an overview, this summary inherently omits details that could be very important to the proper application of the provided geotechnical recommendations. Therefore, this report should be read in its entirety prior to implementation into design and construction. During the subsurface exploration, the test pit method of ground investigation was employed and consisted of five pits due the firm subsurface condition observed. The investigations were conducted from August to September 2022 in Maridi, for the construction of Argo-warehouses, Fruit-processing facility, multipurpose facility, open market, and 20Km road. This investigation process consisted of two stages of investigation which are site surface and sub-surface exploration.

Below is a summary of the output with respect to our observations all based on our observations at the site, interpretation of the field data obtained during this exploration as well as our experience with similar subsurface conditions and projects; Based on the architectural information from the drawing, the proposed structures are; one Open market place, one fruit processing unit, one large(1500MT) ago-warehouse, 6 medium(600MT) ago-warehouses and a 20 Km Road. The designer should carefully analyse the information in this report for proper guidance. Based on the anticipated structural loads and the subsurface conditions encountered in our test pit, we recommend that foundations be designed for an allowable bearing pressure value not exceeding of **246.9 Kpa** foundation depth not less than **1.0m**. Ground water was not encountered in the pit and good ground slopes that provided good drainage for runoff water, in term of semiology, Maridi is considered in medium seismic according to recent by think hazard for more go to this link https://thinkhazard.org/en/report/74-south-sudan/EQ

1.0 INTRODUCTION

Soil investigation refers to exploring the soil properties of construction site thoroughly visual inspection and carrying out laboratory tests or field tests depending on the nature of the project. The investigation is crucial to determine the engineering properties of subsurface soil which include but not limited to the bearing capacity of the soil, stratigraphy (soil profiling) and water level for the design of an economical and safe foundation and most importantly provide remedial measure for safety of and adjacent structure.

As part of the requirement in construction and by relevant authorities in government i.e., Ministry of health land and infrastructure and UNICEF South Sudan, on Saturday,16, August.2022, a team conducted geotechnical investigation of construction site for an Open market place, building in central Maridi– Paced (CES) South Sudan, Plot land of 40m by 60mSq.M. that belongs to ACTED South Sudan. The test was conducted by a registered Engineer, **Eng. Yossief Ghirmay, Eng Mussie Solomun** assisted by three technicians.

1.1 OBJECTIVES

The objectives of the investigation were,

- To determine the bearing capacity of the soil to be used to design substructure
- Asses the geotechnical suitability of the site for the proposed site
- To Study the strata of the soil, provide soil profile as well as safety measures to any nearby structures
- To mark water level, foresees and provide remedial measure for the dangers that might arise due to ground water.

1.2 SCOPE

The scope of the investigation comprised of,

- Excavation of trial pit of 1 meter for soil profiling (five trial pit for a built-up area of about 2-meter square)
- Conducting inside penetration test using Dynamic cone penetrometer (DCP) to assess the penetration resistance of the cone by the soil for computation of bearing capacity

- To determine the depth of underground water if encountered
- Finally, analysis of collected Data and preparation of geotechnical report.
- Carrying out necessary laboratory tests.
- Performing engineering analysis of filed and laboratory findings.

2.0 SITE AND SUBSURFACE CONDITIONS

2.1 SITE DESCRIPTION

The proposed sites are located in Maridi county, Western equatorial state, the soil type was found to be sedimentary rock for all the sites,

Table 1.1: List of project activities, location, and land size (source: field team)

Project activities	Project location	County	Land size	Total area	Distance
Multi-purpose units	Jebel mufatish	Maridi	100m by 120m	12000m^2	1.5km
Fruit processing factory	Suk khamthin 50	Maridi	30m by 25m	750m^2	500m
Open market	Suk waide	Maridi	40m by 60m	2400m^2	2km
600 MT Agro-Warehouse	Jumara	Maridi	60m by 60m	3600m^2	7km
600 MT Agro-Warehouse	Nagbaka	Maridi	80m by 60m	4800m^2	6km
600 MT Agro-Warehouse	Bahra-olo	Maridi	100m by 100m	10,000m^2	
600 MT Agro-Warehouse	Kwange	Maridi	70m*70m	4,900 m^2	
1500MT Agro-Warehouse	Maridi-2	Maridi	62m by 80m	4960 m^2	20Km

2.2 SITE TOPOGRAPHY AND CLIMATIC DESCRIPTION

2.2.1 SITE LOCATION AND TOPOGRAPHY

2.2.1.1 MARIDI MULTI-BUSINESS UNIT AT JEBEL MUFATISH

The land size: 100m by 120m giving total area as 12000m^2. Located at the top of the mountain with the water tank (source for drinking water for the Maridi, Town.

Proposed site: The area of the project goes up-to the small hill (Jebel mufatish areas) then two hills on the other side (northern side). There's water reservoir in a distance of 33m (water tank is 491.48 m3). In litres, this is about 491478.75l and this amount of water is used by Maridi municipality for drinking. River Maridi is about 1.5km from project site.

The general soil type of the area is loam soil having black loam colour up-to a depth of 40 cm and then shifts to red alluvial soil.

Fig 2.1: Multi-business and training centre Maridi Central, Maridi

2.2.1.2 MARIDI FRUIT PROCESSING FACTORY AT SUK KHAMTHIN

The land size: 30m by 25m giving total area as 750m^2. This facility is located near Eden bank almost near the Maridi, Town square. The site is located within the Maridi town and hence no need for access road construction or any work of bush clearing. The general soil type of the area is loam soil having black loam colour up-to a depth of 40 cm and then shifts to red alluvial soil.

Fig 2.2: Fruit processing factory, Maridi Central, Maridi

2.2.1.3 MARIDI OPEN MARKET AT SUK WAIDE

The land size: 40m by 60m giving total area as 2400m^2. The site is located to the north eastern part of the town and has very good mobilization and transportation access. The general soil type of the area is loam soil having black loam colour up-to a depth of 40 cm and then shifts to red alluvial soil.

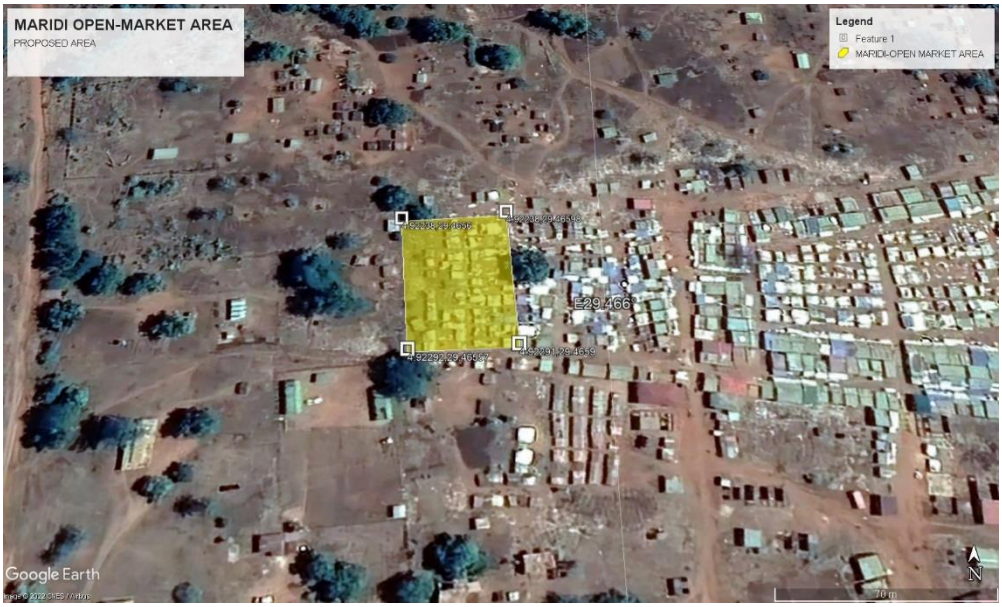


Fig 2.3: Open market center, Maridi Central, Maridi

2.2.1.4 600MT AGRO-WAREHOUSE AT BAHRA-OLO, MARIDI

The land size:100m by 100m giving total area as 10,000m^2. Located on the east-side of the road from Maridi to Juba, Barawel under payam of Mambe is 45 km away from maridi and 15km away from Mambe. The proposed area will need bush clearing at the beginning of the construction stage but there is no problem of access from the main Road, however the road has incurred erosion due to continuous and high amounts of rainfall. The general soil type is sedimentary soil of river sand type.

Fig 2.4: 600MT Warehouse, Barawel, Maridi

2.2.1.5 600MT AGRO WAREHOUSE AT NAGBAKA, MARIDI

The land size :80m by 60 m giving total area of 4800m^2. Located North-west at about 15 km from Maridi Central. Found on the right side of Maridi-Yambio road at least 5Km from the main road. The proposed area will need bush clearing at the during the initial stages of construction time. The general soil type of the area is loam soil having black colour up-to a depth of 40 cm and then shifts to red loam soil.

Fig 2.5: 600MT Warehouse, Nagbaka, Maridi

2.2.1.6 600MT AGRO-WAREHOUSE AT JUMARA, BUROKOBORA VILLAGE, MARIDI

The land size: 60m by 60m giving total area as 3600m^2.
Located 5Km away from Maridi town to the North-west direction along the Maridi-Yambio Road on (left-side of the road). The road is in need of maintenance since it has faced heavy rainfall erosion and hence access is one problem. The soil is black loam soil up-to a depth of 30cm and followed by red alluvial soil layer. Ground water levels are high, and water is easily found at depths below 80cm.

Fig 2.7: 600MT Warehouse, Burokora, Maridi

2.2.1.7 600MT AGRO-WAREHOUSE AT KWANGE, MARIDI

The land size: 70m by 70m giving total area as 4900m^2.
Located 7.5Km away from Maridi town to the South direction along the Maridi-Rosolo Road on (Right-side of the road). The road is in need of maintenance since it has faced heavy rainfall erosion and hence access is one problem. The soil is black loam soil up-to a depth of 30cm and followed by red alluvial soil layer. Ground water levels are high, and water is easily found at depths below 80cm.

Fig 2.8: 600MT Warehouse, Kwange, Maridi

2.2.1.8 1500MT AGRO-WAREHOUSE AT MARIDI-2, MARIDI COUNTY

The land size: 62m by 80m giving total area as 4960m^2.
Located 20Km away from central Maridi town to the North-west direction. The road needs maintenance since it has faced heavy rainfall erosion and hence access is one problem. There is no need for bush clearing for the site. A basaltic like rock formation is visible around the area and this site is having a steep slope going northward from the proposed site. The soil around the rock formation is black loam soil up-to a depth of 30cm and followed by red alluvial soil layer. Ground water levels are high, and water is easily found at depths below 80cm.

Fig 2.6: 1500MT Warehouse, Maridi-2, Maridi

2.2.2 GENERAL SITE CLIMATIC DESCRIPTION

In general, the temperatures of Maridi are high throughout the year with distinct characteristics of dry and rainy season. The monthly average minimum temperature ranges from 18.3 ˚C -23.7 ^{0}C and the highest monthly average temperature is mostly recorded in either January or February with ranges from 28.4^{0}C to 36.5^{0}C. The annual rainfalls range from 500 to 1500 millimetres in a year across South Sudan. The projects are in the green belt which has annual rainfalls of between 1400 and 1500 millimetres. Based on past meteorological records, Maridi's annual rainfall was 1443. While the project area has historically been known to have considerable rainfall as shown above, global warming has affected the rainfall patterns, with general decrease in rainfalls and shrinking of rain supported agriculture based on the studies by Funk and others published in 2011.

The prevailing wind always comes from south, nevertheless in January and February wind prevails from north-to-north west directions.

2.3 SITE GEOLOGY

The site and its surrounding were observed to have loam soil, no any type of rock in this site.

Soil test at 40 cm depth have shown black soil, and at about 80cm depth it is all water.
The soil is generally, same black soil from surface grades to 2.5 meter provided low penetration resistance during DCP test

3.0 SUBSURFACE CONDITIONS

3.1 GENERAL

The subsurface conditions described in the next sub chapter is of a trial pit which is a representative and were used to gather information about the subsurface condition of the site, the information was obtained by geotechnical engineering judgement through visual inspection and analysis of data obtained from a DCP test.

3.2 SURFICIAL SOILS

Thin layer of surficial soil about 25cm from the ground surface. Surficial soils are typically a dark-coloured soil material containing roots, fibrous matter, and/or other organic components, and are generally unsuitable for engineering purposes. No laboratory testing has been performed to determine the organic content or horticultural properties of the observed surficial soil materials. Therefore, for landscaping or gardening work for instance planting of flowers there is need to borrow a suitable material.

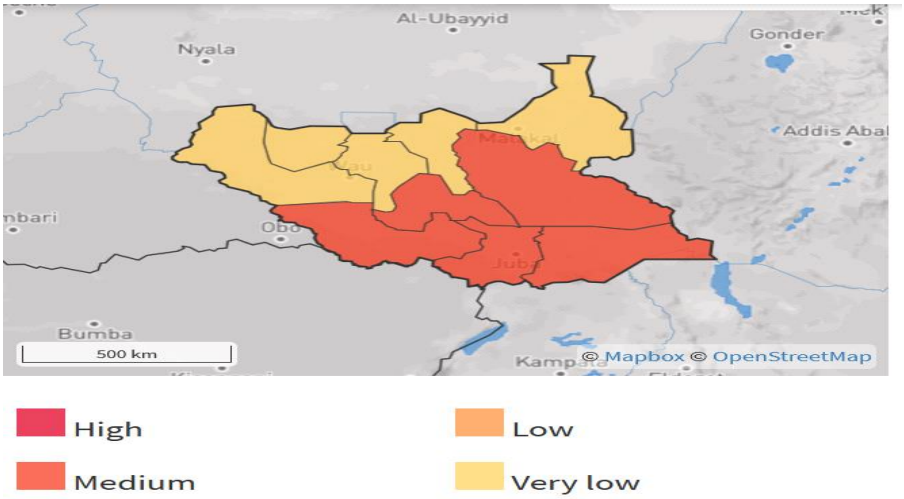
3.3 RESDUAL SOIL

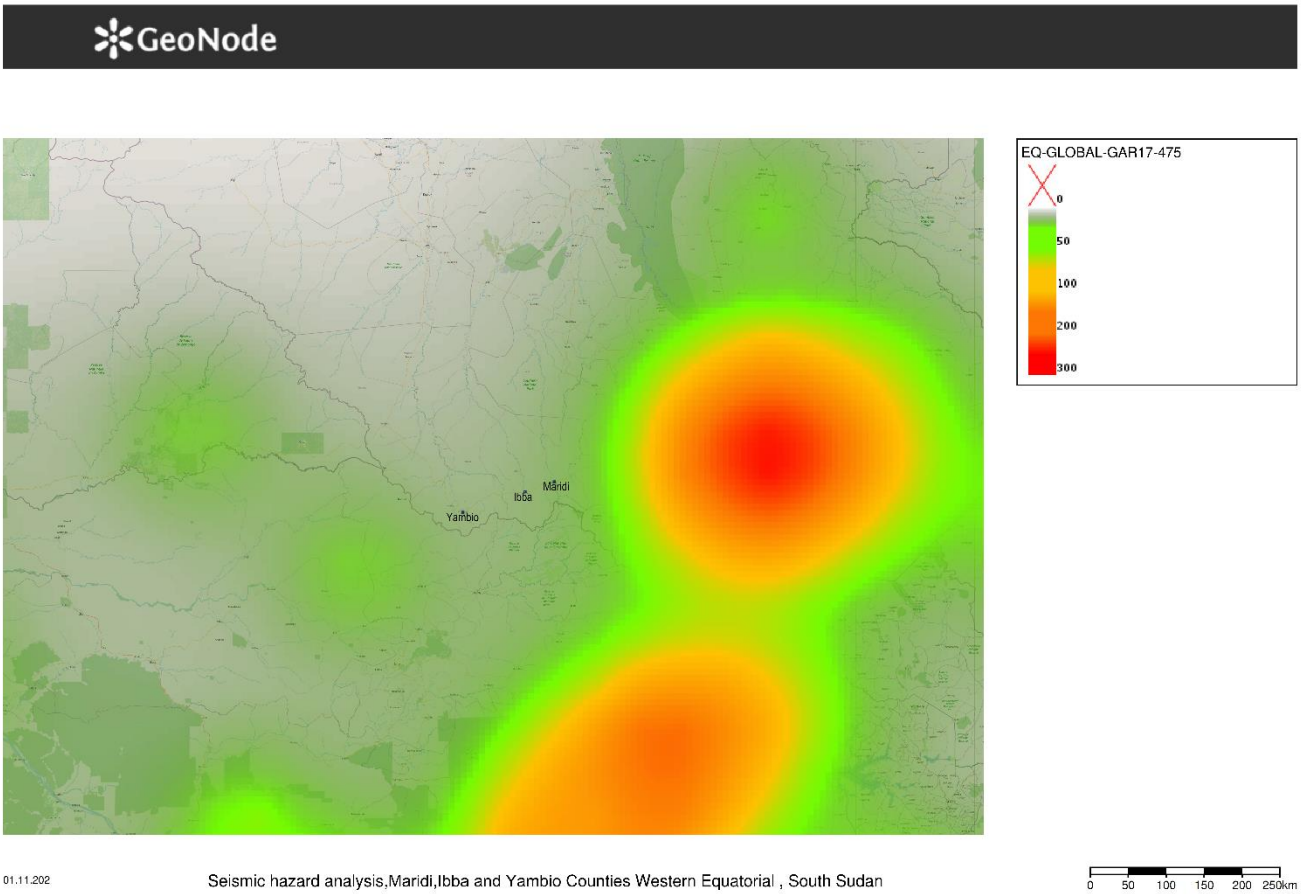
Residual soils, formed by the in-place, were encounter SEDIMENTARY ROCK, erred in the test pit. Sampled residual sample were same put described as (CH), Sandy Silt was encountered from 0.20m to 2.00m, no water level ground surface hence the dynamic cone penetration resistances within the sampled strata were fair.

3.4 SUBSURFACE WATER

when subsurface water is encountered during excavation or drilling, the pits have to be left covered and undisturbed to allow the water level to stabilize for about 24 hours. The actual level of the static sub surface water is there after measured using a tape measure. In this case, the ground on has water encountered in the excavated pit. However, fluctuations in soil moisture can be anticipated with changes in precipitation, run-off, and season.

4.0 SEISMOLOGICAL HISTRY





4.1 Earthquake map of South Sudan by Think hazard

earthquake hazard is classified as **medium** according to the information that is currently available by Think hazard. This means that there is a 10% chance of potentially-damaging earthquake shaking in your project area in the next 50 years. Based on this information, the impact of earthquake should be considered in all phases of the project, in particular during design and construction. Project planning decisions, project design, and construction methods should consider the level of earthquake hazard. Further detailed information should be obtained to adequately account for the level of hazard from https://thinkhazard.org/en/report/74-south-sudan/EQ

6.0 FIELD INVESTIGATIONS

6.1 TEST PIT EXCAVATION

Five test pits were excavated, of average widths of 1.0m and lengths of 1.0m, just enough to allow easy movement for the person doing the excavation, and carrying out DCP test, the excavation was done up to 2.0m and, that make further excavation and it was give required information.

6.2 SOIL SAMPLING

Samples were obtained from the boreholes in the clay soil layer with good recovery we packed the materials in sacks for testing and description purposes. Not that the type, locating and number of samples methods were determined by ministry of road and bridges central laboratory.

6.2.1 LIST OF LABORATORY TESTING

In order to determine the physical. Mechanical and chemical properties of the soil, Laboratory test were performed on selected samples from boreholes. The following tests are performed according to American society for testing material (ASTM)and/or British standard (BS)

1. BS 1377: 1990-part 2 (Amd .9027/96) Test 9.2 practical size analysis of soil
2. BS 1377: 1990 part2 (Amd .9027/96), liquid limit, plasticity index of soils'
3. Determination of specific gravity of particles ASTM D- 854, AASHTO T-100
4. ASTM D 2216-98 Laboratory Determination water (Moisture) content of soil
5. B.S 1377: 1990 And. 9028-96 Determination of sulphate content soils,

1.1	Particle Size			BS1377:1990Part2 Amd.9027/96)Test9.2	Standard Test Method for Particles-Size Analysis of Soils'.
1.2	AtterbergLimits			BS1377:1990Part2 Amd.9027/96),	Liquid Limit, Plastic Limit and Plasticity Index of Soils'.

No.	Test	Illustration	ASTM No.	Title of Standard
1.	Classi ication and Index Tests			
1.1	Moisture Content		D2216-05	Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
1.2	BulkDensity		D7263-09	Standard Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens
2.	Streng th Tests			

6.2.2 CHEMICAL TEST RESULTS

It is knowing that the sulphate salts in solution will attack concrete beyond a certain threshold. The degree of the attack depends upon.

- The results of concentration of sulphate present.
- Type of cement and aggregate used.
- Water of table and mobility of ground water and its PH.
- The quality of concrete.

The results of the chemical tests given in table. show that the sulphate and chloride content in this, soil. The suitable type of cement for location is recorded.

The danger anticipated from chloride attack on adopting thick cover for the steel reinforcement along with high cement content.

Based on the above it is recommended to use: -

- **Ordinary Portland cement (OPC)**
- **Minimum cement content of 300kg/m^3**
- **Maximum free water to cement ratio of 0.55**

Chemical test Results.

BH NO	PEDTH (M)	MATERIAL	SULPHATECONTENT SO_3(%)	CHLORIDECONTENT Cl (%)	PH value
BH 1	2	Alluvial Deposits	0.02281	0.02070	8.7
BH2	1.5	Alluvial Deposits	0.02253	0.02079	8.5
BH3	1.5	Alluvial Deposits	0.02266	0.02075	.8.8
BH4	2	Alluvial Deposits	0.02385	0.02080	8.5
BH5	2	Alluvial Deposits	0.02371	0.02083	8.6

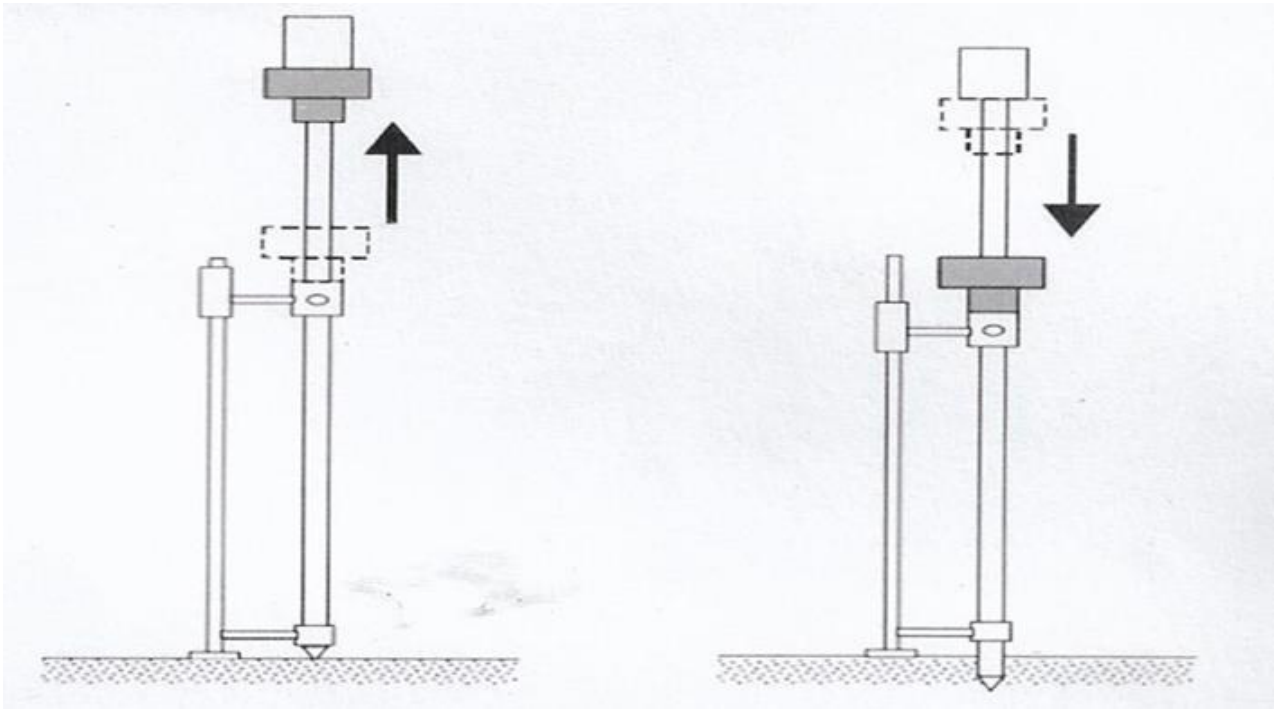
6.3 DYNAMIC CONE PENETRATION TESTS

Penetration tests were carried out "in situ" using a Dynamic Cone Penetrometer at suitable depths of the test pit. This testing provides a measure of a material's in-situ resistance to penetration. The test is performed by driving a 60^{o} metallic cone into the ground by repeatedly striking it with a hammer of standard weight dropped from a standard height. The penetration of the cone is measured after a suitable number of blows and is recorded to provide a continuous measure of shearing resistance up to the required distance below the ground surface.

DCP test results can be correlated with number of strokes measured with standard penetration test (SPT). the results are correlated by equalizing the penetration energy within the unit volume of soil. As a result, equivalent SPT number of strokes equals DCP number strokes for 10cm of penetration depth multiplied by 0.7 as shown below.

Nspt = 0.70 * Nt13

6.4 PICTORIAL PRESENTATIONS OF THE INVESTIGATION



(a) Before hammer dropping **(b) After hammer dropping**

7.0 FINDINGS

After carrying out DCP test and analysis, below is a representation of the results as obtained from field test.

Exscivtion the borehole

DCP test result

Ministry of Roads and Bridges
Directorate of Quality Control, Materials and Research
Central Materials Testing Laboratory

Geotechnical Investigation of Soil Safe Bearing Pressures

Dynamic Cone Penetrometer Test (DCP) - Foundations.

BH 04			BH 05			BH 06		
Depth m	BC KN/m²	No.Blows	Depth m	BC KN/m²	No.Blows	Depth m	BC KN/m²	No.Blows
0	0	0	0	0	0	0	0	0
-0.1	24	3	-0.1	32	4	-0.1	47	6
-0.2	55	7	-0.2	24	3	-0.2	63	8
-0.3	47	6	-0.3	32	4	-0.3	63	8
-0.4	39	5	-0.4	39	5	-0.4	47	6
-0.5	63	8	-0.5	32	4	-0.5	55	7
-0.6	79	10	-0.6	47	6	-0.6	71	9
-0.7	87	11	-0.7	63	8	-0.7	79	10
-0.8	103	13	-0.8	111	14	-0.8	95	12
-0.9	126	16	-0.9	103	13	-0.9	126	16
-1	150	19	-1	118	15	-1	150	19
-1.1	174	22	-1.1	134	17	-1.1	174	22
-1.2	189	24	-1.2	142	18	-1.2	189	24
-1.3	205	26	-1.3	158	20	-1.3	205	26
-1.4	229	29	-1.4	166	21	-1.4	221	28
-1.5	253	32	-1.5	182	23	-1.5	245	31
-1.6	268	34	-1.6	213	27	-1.6	268	34
-1.7	292	37	-1.7	237	30	-1.7	292	37
-1.8	324	41	-1.8	253	32	-1.8	308	39
-1.9	347	44	-1.9	276	35	-1.9	316	40
-2	395	50	-2	300	38	-2	332	42
-2.1	0	0	-2.1	316	40	-2.1	395	50
			-2.2	363	46	-2.2	0	0
			-2.3	395	50			
			-2.4	0	0			
Depth @-1.9m (BC-347)KN/m²			Depth @-2.2m (BC-363)KN/m²			Depth @-2.0m (BC-332)KN/m²		

Project :	Geotechnical Investigation of Open market Center Building
Location:	Maridi, South Sudan, Building Area 1650 Sq.M
Property/Client :	ACTED, South Sudan
Date :	21/9/2022

Report and Checked By: Daniel Vinansio

Approved By : Eng. Anthony Lodongi

MINISTRY OF ROADS & BRIDGES
21 SEPT 2022
CENTRAL MATERIALS LABORATORY

Ministry of Roads and Bridges
Directorate of Quality Control, Materials and Research
Central Materials Testing Laboratory

Geotechnical Investigation of Soil Safe Bearing Pressures

Dynamic Cone Penetrometer Test (DCP) - Foundations.

BH 01			BH 02			BH 03		
Depth m	BC KN/m²	No.Blows	Depth m	BC KN/m²	No.Blows	Depth m	BC KN/m²	No.Blows
0	0	0	0	0	0	0	0	0
-0.1	39	5	-0.1	32	4	-0.1	24	3
-0.2	32	4	-0.2	32	4	-0.2	32	4
-0.3	47	6	-0.3	39	5	-0.3	24	3
-0.4	32	4	-0.4	39	5	-0.4	47	6
-0.5	39	5	-0.5	39	5	-0.5	47	6
-0.6	55	7	-0.6	126	16	-0.6	95	12
-0.7	47	6	-0.7	71	9	-0.7	95	12
-0.8	87	11	-0.8	87	11	-0.8	71	9
-0.9	87	11	-0.9	79	10	-0.9	87	11
-1	103	13	-1	95	12	-1	79	10
-1.1	126	16	-1.1	111	14	-1.1	111	14
-1.2	158	20	-1.2	142	18	-1.2	118	15
-1.3	189	24	-1.3	166	21	-1.3	158	20
-1.4	213	27	-1.4	205	26	-1.4	182	23
-1.5	237	30	-1.5	237	30	-1.5	213	27
-1.6	245	31	-1.6	261	33	-1.6	245	31
-1.7	261	33	-1.7	268	34	-1.7	284	36
-1.8	284	36	-1.8	292	37	-1.8	300	38
-1.9	308	39	-1.9	324	41	-1.9	324	41
-2	316	40	-2	339	43	-2	395	50
-2.1	332	42	-2.1	395	50	-2.1	0	0
-2.2	339	43	-2.2	0	0			
-2.3	355	45						
-2.4	395	50						
-2.5	0	0						
Depth @-2.3m (BC-355KN/m²)			Depth @-2.0m (BC-339KN/m²)			Depth @-1.9m (BC-324)KN/m²)		

Project :	Geotechnical Investigation of Open market Center Building
Location:	Maridi, South Sudan, Building Area 1650 Sq.M
Property/Client :	ACTED, South Sudan
Date :	21/09/2022

Report and Checked By: Daniel Vitalsio

Approved By : Eng. Anthony Lodongi

MINISTRY OF ROADS & BRIDGES
21 SEPT 2022
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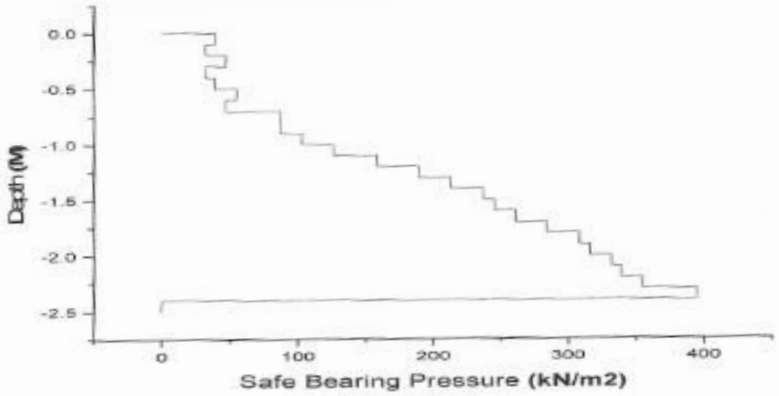
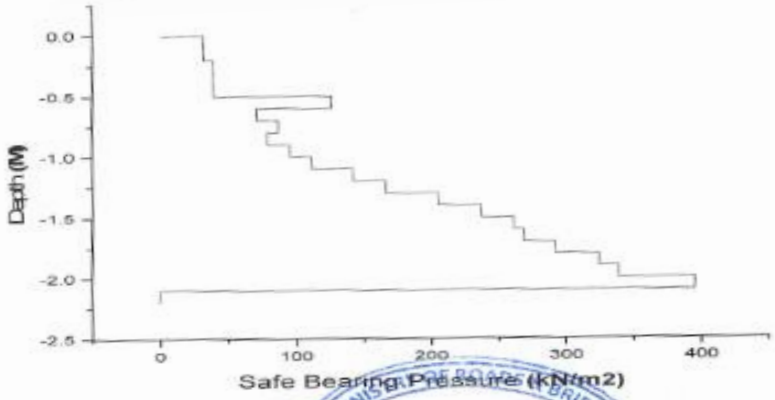
Geotechnical Investigation of Open Market Center Building, Maridi, South Sudan, Depth **-2.3M** (BC-355kN/m2) @ **(BH No.1)**



Geotechnical Investigation of Open Market Center Building, Maridi, South Sudan, Depth **-2.0M** (BC-339kN/m2) @ **(BH No.2)**



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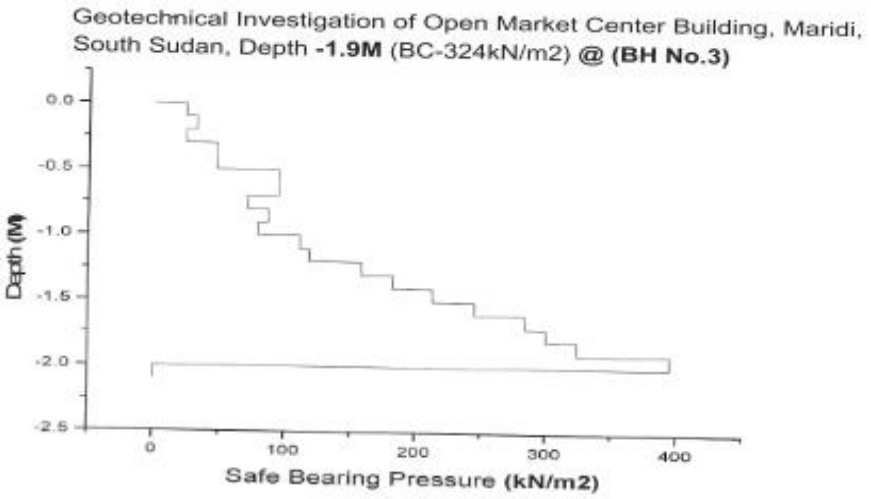

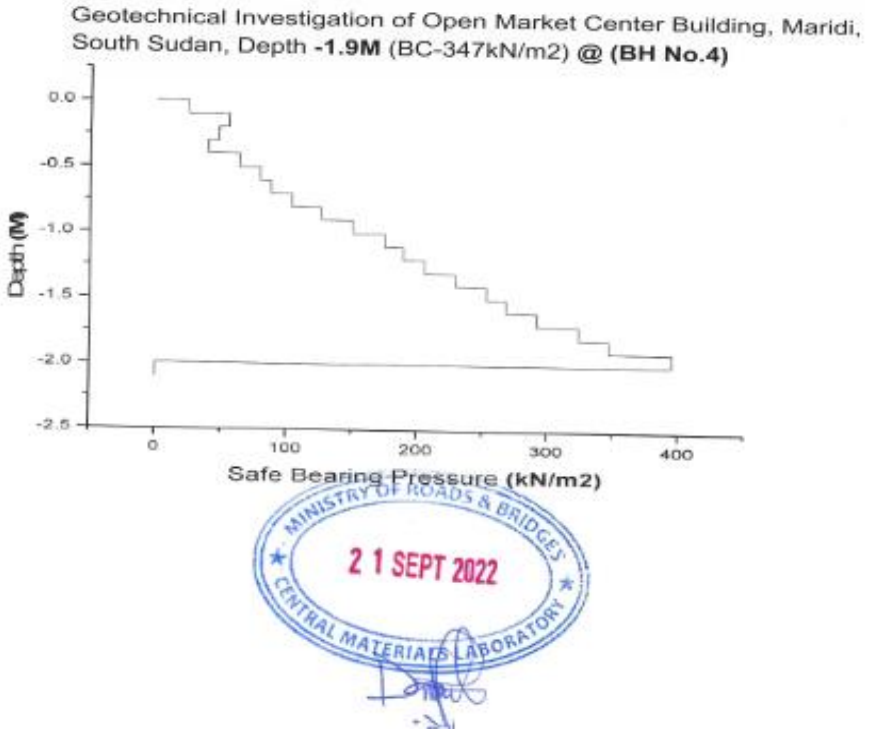

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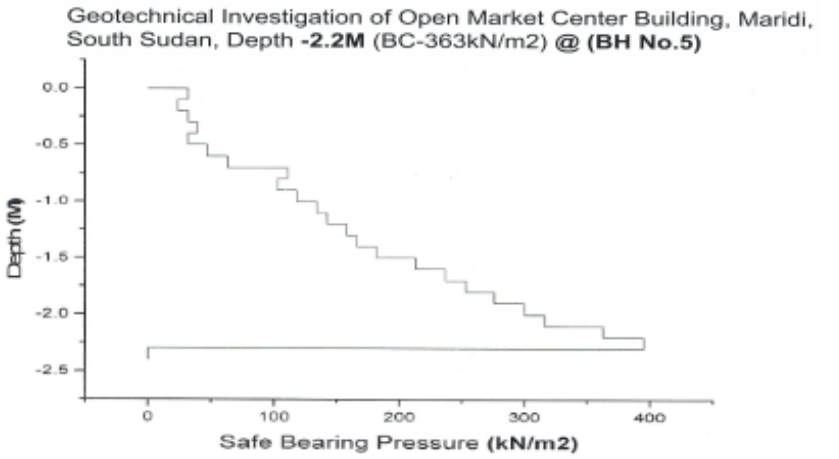
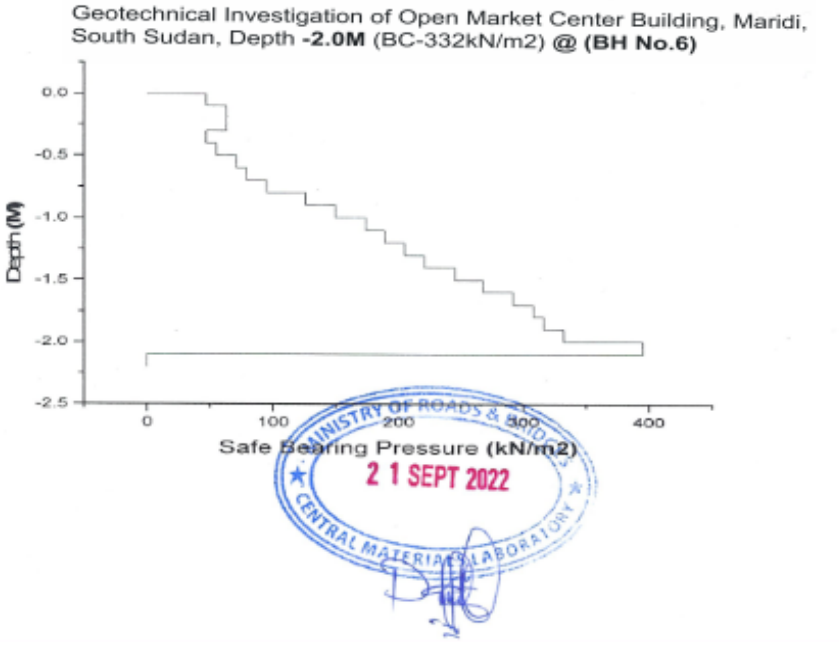

Geotechnical Investigation of Open Market Center Building, Maridi, South Sudan, Depth -2.2M (BC-363kN/m2) @ (BH No.5)
Depth (M)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
0
100
200
300
400
Safe Bearing Pressure (kN/m2)


Geotechnical Investigation of Open Market Center Building, Maridi, South Sudan, Depth -2.0M (BC-332kN/m2) @ (BH No.6)
Depth (M)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
0
100
200
300
400
Safe Bearing Pressure (kN/m2)

MINISTRY OF ROADS & BRIDGES
21 SEPT 2022
CENTRAL MATERIALS LABORATORY

0							
TEST PIT LOG							
PROJECT	GEOTECHNICAL INVESTIGATION REPORT FOR SITE ON PLOT MARIDI OPEN MARKET						
EXCAVATION METHOD: Manula excavtion by ha DATE:16/08/2022							
Depth (m)	Ground water level	Description of stratum	Legend	Level	Bearing Capacity Kpa	KEY	
0.00		Top soil		0.25			
0.40	No	Light Black loam soil				TO SOIL	
0.80		Light Red loam soil		1.05		CH	
1.00							
1.50	Yes						
2.00							

Other findings from visual inspection

- The soil is predominantly black loam layer from the surficial up to 0.4cm depths and red loam soil from 0.4cm up to 0.8.
- The slope of the excavation was stable and the no water level encountered during the excavation of the pit.

7.1 SOIL PROFILE

Soil stratification of the pit

8.0 CONCLUSIONS AND RECOMMENDATIONS

- The soil is predominantly black loam layer from the surficial up to 0.4cm depths and red loam soil from 0.4cm up to 0.8.
- The Ground water table was being encountered in the excavated pit as shown in the test pit log details. Therefore, it is considered that ground water has effect on foundation soils up to excavated depths.
- It is also recommended that the structural Engineer uses an Allowable bearing capacity of

  246.9.0 Kpa and at depths of not less than **1.2m**, for foundation design.
- The footing foundation type is recommended to be isolated footing type unless otherwise the profile dictates.
- Darning It is recommended to protect the foundation ground and excavation from surface water both during and after construction by providing proper.
- Backfill Works Generally the material to be used for backfilling under slap and behind underground walls shall be a murram soil –rock mixture, which is free organic matter.
- For the cut slopes in excavation, it is recommended that the temporary cut slopes on steeper than 1 horizontal to 2 verticals. Cut slopes should be protected from concentrated water flows. Some sloughing and erosion should be expected.
- It is recommended that the exterior grades be designed to promote rapid runoff of surface water from the structures.
- There is a small part in the site that must be addressed before the construction of the

built foundation begins.