GEOTECHNICAL INVESTIGATION

PROPOSED BONDENI ESTATE ON LR NO. 451/881- F/R NO. 75/10 NAKURU.

Prepared for: National Housing Corporation,
P.O Box 30257-00100,
Nairobi.

Attention: Eng. Wilfred Makutha and Eng. Judith G. Limungi

2 copies - National Housing Corporation
1 copy - Terraconsult Kenya Limited, Nairobi

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1. INTRODUCTION

Terraconsult was retained by National Housing Corporationto carry out a detailed geotechnical investigation and provide design advice for Proposed Bondeni Estate on Lr No. 451/881- F/R No. 75/10 Nakuru.

Engineers Wilfred Makutha and G. Limungi provided all communication on the proposed scope of the subsurface investigation.

This report presents the findings of geotechnical survey carried out at the proposed project site. It primarily contains results from field borehole drilling, insitu tests and laboratory tests. It also includes analysis of the test results, field observations and presentation of factual geotechnical findings.

All the fieldwork was carried out according to BS 5930: 2015 (code of practice for site investigations). Laboratory tests were done as stipulated in the British Standards (BS 1377); the American Society for Testing Materials (ASTM) designated D 2938-79 and D 2845-00. Design recommendations are in adherence to the Manual for the Geotechnical Design of Structures to Euro code 7(2013) and BS 8004.

2. SITE AND PROJECT DESCRIPTION

The subject property is located on Moi Road, Nakuru. A topographic map of the area is subsequently appended as Figure 1. According to GPS data, the project site is at an elevation of approximately 1804m above sea level. The project entailed rotary drilling of geotechnical boreholes to obtain core samples for analysis.

3. FIELD AND LABORATORY PROCEDURE

The fieldwork for this investigation was conducted from 22nd to 24th March 2019. It consisted of drilling and sampling three (3) exploratory boreholes to a maximum depth of 25m below existing grade. The drilling equipment consisted of a rotary drilling rig (GY-150) equipped with conventional soil sampling and testing tools. The supervising technician logged the borings and examined the samples as they were obtained. The samples were properly identified by visual inspection, catalogued in wooden core boxes/sealed sample containers and transferred to the laboratory for testing. A geotechnical engineer later reviewed the samples for consistency of description. The photographs of the samples are presented in Appendix B of this report.

Water level measurements were conducted in the open borehole upon completion of drilling. The water was allowed to equilibrate for about 30 minutes before taking the final measurement. The final water rest level is recorded in the borehole logs (Appendix A). It should be noted that the ground water conditions reported above may not necessarily represent stabilized conditions or conditions expected during construction. In addition, assistive drilling water contributes to the level observed in boreholes.

The recovered intact core samples, representative samples from the anticipated foundation depths and the zone of influence of the foundation loadings, were soaked in water for four (4) days to achieve saturation, trimmed to specifications before point load tests (PLT) tests were carried out. The test results are appended to this report. They include computed bearing capacity values from rock cores irrespective of any settlement obtained by use of R. E. Goodman's Formula (Goodman, R.E., 1989) and are applicable at the respective depths indicated.

4. SUBSURFACE CONDITIONS

The borehole elevations and coordinates are provided relative to geodetic datum. The datum for all heights in Kenya is the mean sea level referred to a tide gauge at Kilindini harbour in Mombasa. The horizontal coordinates are reported relative to the Universal Transverse Mercator geographic coordinate system (UTM WGS84). The boreholes were surveyed for horizontal coordinates and geodetic elevations with a hand-held Garmin navigator connected to the Global Navigation Satellite System.

The subsurface soil, rock and ground water conditions encountered in the boreholes are presented on the attached Log of Borehole sheets. The stratigraphic boundaries indicated on the Log of Borehole sheets are inferred from non-continuous samples and observations of drilling resistance and typically represent a transition from one soil or rock type to another. These boundaries should not be interpreted to represent exact planes of geological change. The subsurface conditions have been confirmed in a series of widely spaced boreholes, and will vary between and beyond the borehole locations. The discussion has been simplified in terms of the major soil and rock strata for the purposes of geotechnical design.

4.1 Stratigraphy

The following stratigraphy is based on the borehole findings, as well as the geotechnical laboratory testing conducted on selected representative soil samples.

All boreholes encountered a surficial layer of dark grey, fine grained, moist, loose, non plastic volcanic ash which range in thickness from about 3.0m to 4.0m below existing grade (Elev. 1801.0 ± m to 1800.0 ± m). These volcanic ash layers are underlain by pale brown, fine grained, moderately soft, highly weathered to decomposed tuff. These tuff layers are intercalated with volcaniclastics at various depths in all boreholes. The tuff layers extend to the final depth of the investigation.

4.2 Ground Water

The stabilized ground water table was reported at about 8m below grade.

Borehole	**Depth of Boring**	**Ground Water Table (m)** **After drilling**
Bh 101	25	8.190
Bh 102	25	8.180
Bh 103	25	8.100

Table A1 Ground water table levels

It should be noted that the ground water levels may fluctuate seasonally depending on the amount of precipitation and surface runoff. The depth of unsterilized ground water and caving were measured in each of Boreholes after the drilling work was completed.

4.3 Geotechnical Laboratory Test Results

4.3.1 Native Soil

The geotechnical laboratory testing consisted of sieve and hydrometer analysis and Atterberg Limits tests on selected soil samples. A summary of the results of the samples analyzed is presented below.

Test	**Samples**	**Results**
Sieve and hydrometer analysis and Atterberg limits	Bh 101(3.0-4.5)m	Completely decomposed tuff, non-plastic
	Bh 102 (2.0-4.0)m	Volcanic ash, non-plastic
	Bh 103(0.0-1.5)m	Volcanic ash, non-plastic

Table A2 Summary of Soils Tests

4.3.2 Tuffs

The test carried out for tuffs was point load tests (PLT).

5. DISCUSSION AND RECOMMENDATIONS

The following are based on the factual data obtained from this investigation and are intended for use of National Housing Corporation and their consultants. Contractors bidding or providing services on this project should review the factual data and determine their own conclusions regarding construction methods and scheduling. This report is provided based on these terms of reference and on the assumption that the design features relevant to the geotechnical analysis will be in accordance with applicable codes, standards and guidelines of practice.

5.1 Foundations

5.1.1 Foundation on Native Soil

Laboratory results are subsequently appended in the report. Atterberg's limits portray the soils as non-plasticity. The Standard Penetration test results ('N' Values) obtained weathered/disturbed soil zone varied from about 6 to 19 blows per 300 mm of penetration indicating a firm to very stiff consistency at a depth of 2 to 8 m. The allowable safe bearing capacity of the volcanic ash is 50 kN/m^2 based on the SPT values.

If the foundation will be founded between depths of 4.0m to 6.0m, then using the foundation dimensions (width, B, and length, L) and the foundation depth, D_f, the ultimate bearing capacity, q_u, for various footing shapes can be calculated using the equations below:

Strip footings: $q_u = cN_c + \gamma D_f N_q + 0.5\gamma B N_\gamma$

Square foundations: $q_u = 1.3cN_c + \gamma D_f N_q + 0.4\gamma B N_\gamma$

Circular foundations: $q_u = 1.3cN_c + \gamma D_f N_q + 0.3\gamma B N_\gamma$

Rectangular foundations: $q_u = cN_c(1 + 0.3\frac{B}{L}) + \gamma D_f N_q + 0.5\gamma B N_\gamma(1 - 0.2\frac{B}{L})$

Where,

c = Cohesion (16.81 kN/m^2)

$\emptyset°$ = Angle of internal friction (36.45º, see appended Shear box test results).

γ = Effective unit weight of soil (16.49 kN/m^3)

N_c, N_q, N_γ = Terzaghi' s bearing capacity factors for general shear failure (Appendix D)

A minimum factor of safety of 3 (F = 3) is recommended to obtain the safe bearing pressure from the computed ultimate bearing capacity using the equation below;

$$q_s = \frac{q_u}{F}$$

where,

q_s = Safe bearing capacity and,

F = Factor of safety

5.1.2 Foundations on Rock

Bearing Capacities where computed from the Uniaxial Compressive Strength (UCS) using the Goodman (1989) formula. The maximum allowable bearing capacity of the tuff is 200kN/m^2.

$$q_a = q_{ur}(N\emptyset + 1)$$

Where $$N\emptyset = tan^2(45 + \frac{\emptyset}{2})$$

q_a is the allowable bearing capacity;

q_{ur} is the UCS value of the rock;

$\emptyset$ is the angle of internal friction

The point load index ($Is_{(50)}$) and bearing capacity values at various depths of the boreholes are presented in Appendix C.

5.2 Settlement

Settlement of foundations in native soil can be computed using the coefficient of volume compressibility (m_v) obtained from one dimensional consolidation test. Consolidation settlement of native soil due to changes in vertical stress can be computed using the equation below;

$$\rho = \int_0^H m_v \times \Delta\sigma \times H$$

Where,

ρ = Consolidation settlement (m).

m_v = Coefficient of compressibility ($2.142x10^{-4}m^2/kN$).

$\Delta\sigma$ = Change in vertical stress (kN/m^2).

H = Height under stress (m).

5.3 Excavations

Excavations slopes in native soil must be supported using proper shoring systems. Shoring methods depend on the loadings and type of structures in the adjoining plots. Proper design is required to preserve the integrity of the slope and surrounding properties. Temporary slope protection may be necessary to prevent sloughing of soil materials into the excavation. Direct rainfall on such slopes causes rapid erosion. To prevent slope erosion in rainstorms, spray-on product is recommended to bind the soil particles on the surface. Plastic covering can be used to minimize changes in moisture content on the surface of the slope and maintain stability. It is always important that care should be taken when working in unsupported excavations extending below any ground.

5.4 Base Slab on Drainage

The lowest floor slab can be supported on the decomposed tuff but must be compacted. The concrete floor slab must be provided with a capillary moisture barrier and drainage layer. The capillary moisture barrier can be made by placing the slab on a minimum 200 mm layer of clear 19 mm stone compacted by vibration to a dense state. This stone serves also as the drainage media for the subfloor drainage system, which is required. Any aggregate fill placed beneath the floor slab must be compacted to not less than 98% of Standard Proctor maximum dry density.

5.5 Backfilling

The excavated areas should be backfilled with selected approved hard-core or similar material. Backfill below settlement sensitive areas for purposes of levelling the working area should be compacted in lifts 150 mm thick or less, to at least 95 percent Standard Proctor maximum dry density.

6. LIMITATIONS AND RISK

This geotechnical examination has been carried out using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by Terraconsult Kenya Limited and other engineering practitioners, working under similar conditions and subject to the time, financial and physical constraints applicable to this project. The discussions and recommendations that have been presented are based on the factual data obtained from this investigation. It must be recognized that there are special risks whenever engineering or related disciplines are applied to identify subsurface conditions. A comprehensive sampling and testing programme implemented in accordance with the most stringent level of care may fail to detect certain conditions. Terraconsult Kenya Limited has assumed for the purposes of providing design parameters and advice, that the conditions that exist proximal to the sampling point are similar to those found at the sample location. These conditions may differ from those that actually exist. It may not be possible to drill sufficient number of boreholes or sample and report them in a way that would provide all the subsurface information that could affect construction costs, techniques, equipment and scheduling. Contractors and Quantity Surveyors bidding on or undertaking work on this project should be directed to draw their own conclusions as to how the subsurface conditions may affect them, based on their own investigations and their own interpretations of the factual investigation results, cognizant of the risks implicit in the subsurface investigation activities. It must be recognized that the passage of time, natural occurrences, and direct or indirect human intervention at or near the site have the potential to alter subsurface conditions.

The design parameters provided and the engineering discussion are based on the factual data obtained from this investigation made at the site by Terraconsult Kenya Ltd and are intended for use by the owner and his retained designers in the design phase of the project. If there are changes to the project scope and development features the interpretations made from the subsurface information, the geotechnical design

parameters and comments relating to constructability issues and quality control may not be relevant to the revised project. This report was prepared for the express use of National Housing Corporation and is not for use by others. This report is copyright of Terraconsult Kenya Limited and no part of this report may be reproduced by any means, in any form, without the prior written permission of Terraconsult Kenya Limited, National Housing Corporation and their retained design consultants are authorized users. We trust this report provides sufficient information for your present purposes. If you have any questions concerning this report or if we may be of further services to you please do not hesitate to contact our offices.

Sincerely,
Terraconsult Kenya Limited

Issa Ismail, PhD.

Geotechnical Engineer

7. APPENDIX A-Borehole Logs and Section

PROJECT: PROPOSED BONDENI ESTATE, NAKURU TOWN	TERRACONSULT KENYA LIMITED	ELEVATION (m)	1804
LOCATION: NAKURU COUNTY		COORDINATES (UTM-WGS84)	E 0174783 ZONE 37 M
CLIENT: NATIONAL HOUSING CORPORATION.			N 9966951
		DATE(S)	START 22/03/19
			END 24/03/19
	BOREHOLE LOG	**Sheet No:** 1 of 2	
File No: 3-19-16	**Logged By:** Winnie Munene	**Checked By:** Dr. Issa Ismail	
Drilling Method: Rotary	**Drill Bit Type:** 86-101mm Diamond	**Borehole No:** 101	
Drill Rig Type: GY 150T	**Drilled By:** Kelvin Odour	**Depth:** 25.00 m	
Apparent Depth of Ground Water: 13.190 m		**Inclination From Vertical:** 0°	

Depth (m)	ROCK CORE: Run (m)	TCR (%)	RQD (%)	RMR (RQD)	GRAPHIC LOG	MATERIAL DESCRIPTION	Weathering Grade	RMR (Weathering Grade)	Fracture Asperities	Fracture Frequency	Rock Mass Quality	SPT (N-Value)
0												
1	1.5				VOLCANIC ASH	Dark grey, fine grained, weak, non plastic Volcanic ash.						
2												7
	1.5				VOLCANIC ASH	Dark grey, fine grained, weak, non plastic Volcanic ash.						
3												8
4	1.5				TUFF	Pale brown, fine grained, weak, completely decomposed TUFF.						
5												12
	1.5				TUFF	Pale brown, fine grained, weak, completely decomposed TUFF.						
6												16
7	2				TUFF	Pale brown, fine grained, weak, completely decomposed TUFF.						
8												19
9	2	24	0	3	VOLCANOCLASTICS	Pale brown, moderately weathered, altered, fine grained, moderately hard volcaniclastic deposits. characterised by rubbled section.	IV	1	RI	Rubbled	VP	
10												
11	1.5	32	0	3	TUFF	Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Decompos ed	VP	
12												

WEATHERING GRADES
- **I**: Fresh & Hard
- **II**: Slightly Weathered
- **III**: Moderately Weathered
- **IV**: Highly Weathered
- **V**: Completely Weathered
- **VI**: Residual/Soil

FRACTURE ASPERITIES
- **RI**: Rough and Irregular
- **RU**: Rough and Undulating

ROCK MASS QUALITY
- **E**: Excellent
- **G**: Good
- **Fa**: Fair
- **P**: Poor
- **VP**: Very Poor

- **TCR:** Total Core Recovery Ratio
- **RQD:** Rock Quality Designation
- **RMR:** Rock Mass Rating after Bieniawski (1989)

PROJECT: PROPOSED BONDENI ESTATE, NAKURU TOWN	TERRACONSULT KENYA LIMITED	ELEVATION (m)	1804	
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CLIENT: NATIONAL HOUSING CORPORATION.			N 9966951	
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	BOREHOLE LOG	**Sheet No:** 2 of 2		
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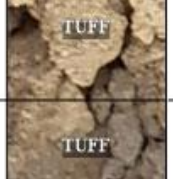
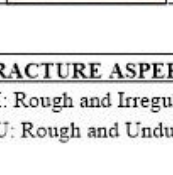
13 – 14	3	33	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Decompos ed	VP	
15 – 16	1.5	24	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Decompos ed	VP	
16 – 17	1.5	37	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Decompos ed	VP	
18 – 19	1.5	23	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Decompos ed	VP	
19 – 20	1	34	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Decompos ed	VP	
20 – 21	2	21	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Decompos ed	VP	
22 – 23	1.5	20	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Decompos ed	VP	
24 – 25	1.5	19	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Decompos ed	VP	

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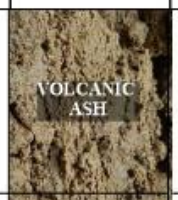
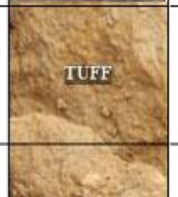
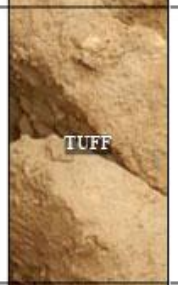
LOCATION: NAKURU COUNTY		COORDINATES (UTM-WGS84)	E 0174772 ZONE 37 M
CLIENT: NATIONAL HOUSING CORPORATION.			N 9966933
		DATE(S)	START 22/03/19
			END 24/03/19
	BOREHOLE LOG	**Sheet No:** 1 of 2	
File No: 3-19-16	**Logged By:** Winnie Munene	**Checked By:** Dr. Issa Ismail	
Drilling Method: Rotary	**Drill Bit Type:** 86-101mm Diamond	**Borehole No:** 102	
Drill Rig Type: GY 150T	**Drilled By:** Kelvin Odour	**Depth:** 25.00 m	
Apparent Depth of Ground Water: 8.180 m		**Inclination From Vertical:** 0°	

Depth (m)	ROCK CORE: Run (m)	TCR (%)	RQD (%)	RMR (RQD)	GRAPHIC LOG	MATERIAL DESCRIPTION	Weathering Grade	RMR (Weathering Grade)	Fracture Asperities	Fracture Frequency	Rock Mass Quality	SPT (N-Value)
0 – 1	2					Dark grey, moist, fine grained, loose, non plastic Volcanic ash.						6
2 – 3	2					Dark grey, moist, fine grained, loose, non plastic Volcanic ash.						9
4 – 5	2					Pale brown, fine grained, weak, completely decomposed TUFF.						11
6 – 7	1.5	24	0	3		Pale brown, relatively soft, moderately weathered TUFF. Characterised by open, rough and irregular fracture surfaces. RUBBLED.	III	3	RI	>20	VP	
8 – 9 – 10	3	16	0	3		Pale brown, relatively soft, highly weathered TUFF. Characterised by open, rough and irregular fracture surfaces. RUBBLED.	IV	1	RI	>20	VP	
11 – 12	1.5	33	15	3		Pale brown, relatively soft, moderately weathered TUFF. Characterised by open, rough and irregular fracture surfaces.	III	3	RI	>20	VP	
13	1.5	33	22	3		Pale brown, relatively soft, highly weathered TUFF. Characterised by open, rough and irregular fracture	IV	1	RI	>20	VP	

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LOCATION: NAKURU COUNTY		COORDINATES (UTM-WGS84)	E 0174772 ZONE 37 M
CLIENT: NATIONAL HOUSING CORPORATION.			N 9966933
		DATE(S)	START 22/03/19
			END 24/03/19
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						surfaces. RUBBLED.						
14	1.5	35	23	3	TUFF	Pale brown, relatively soft, highly weathered TUFF. Characterised by open, rough and irregular fracture surfaces. Partly rubbled.	IV	1	RI	>20	VP	
15	1.5	20	0	3	TUFF	Pale brown, relatively soft, highly weathered TUFF. Characterised by open, rough and irregular fracture surfaces. RUBBLED.	IV	1	RI	>20	VP	
16	1.5	20	0	3	VOLCANOCLASTICS	Pale brown, moderately weathered, fine grained, moderately hard volcaniclastic deposits. Completely rubbled.	III	3	RI	>20	VP	
17	1.5	33	0	3	VOLCANOCLASTICS	Pale brown, moderately weathered, fine grained, moderately hard volcaniclastic deposits. Completely rubbled.	III	3	RI	>20	VP	
18	1.5	20	0	3	TUFF	Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	>20	VP	
19	1.5	14	0	3	TUFF	Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	>20	VP	
20	1.5	28	0	3	VOLCANOCLASTICS	Pale grey, moderately weathered, fine grained, moderately hard volcaniclastic deposits. Completely rubbled.	III	3	RI	>20	VP	
21	1	26	0	3	VOLCANOCLASTICS	Pale grey, moderately weathered, fine grained, moderately hard volcaniclastic deposits. Completely rubbled.	III	3	RI	>20	VP	
22												
23												
24												
25												

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LOCATION: NAKURU COUNTY		COORDINATES (UTM-WGS84)	E 0174760 ZONE 37 M
CLIENT: NATIONAL HOUSING CORPORATION.			N 9966920
		DATE(S)	START 22/03/19
			END 24/03/19
	BOREHOLE LOG	**Sheet No:** 1 of 2	
File No: 3-19-16	**Logged By:** Winnie Munene	**Checked By:** Dr. Issa Ismail	
Drilling Method: Rotary	**Drill Bit Type:** 86-101mm Diamond	**Borehole No:** 103	
Drill Rig Type: GY 150T	**Drilled By:** Kelvin Oduor	**Depth:** 25.00 m	
Apparent Depth of Ground Water: 8.100 m		**Inclination From Vertical:** 0°	

Depth (m)	ROCK CORE: Run (m)	TCR (%)	RQD (%)	RMR (RQD)	GRAPHIC LOG	MATERIAL DESCRIPTION	Weathering Grade	RMR (Weathering Grade)	Fracture Asperities	Fracture Frequency	Rock Mass Quality	SPT (N-Value)
0 – 1	1.5					Dark grey, fine grained, loose, non plastic Volcanic ash.						
1 – 2	1.5					Dark grey, fine grained, loose, non plastic Volcanic ash.						7
2 – 3												
3 – 4	1.5					Pale brown, fine grained, weak, completely decomposed TUFF.						8
4 – 5												
5 – 6	1.5					Pale brown, fine grained, weak, completely decomposed TUFF.						10
6 – 7												
7 – 8	1.5					Pale brown, fine grained, weak, completely decomposed TUFF.						11
8 – 9												
9 – 10	1.5					Pale brown, fine grained, weak, completely decomposed TUFF.						8
10 – 11	1.5					Pale brown, fine grained, weak, completely decomposed TUFF.						
11 – 12	1.5	22	14	3		Pale brown, relatively soft, highly weathered TUFF. Characterised by open, rough and irregular fracture surfaces.	IV	1	RI	>20	VP	
12						Pale brown, fine grained, moderately soft, highly weathered TUFF.				Deco		

WEATHERING GRADES
- **I**: Fresh & Hard
- **II**: Slightly Weathered
- **III**: Moderately Weathered
- **IV**: Highly Weathered
- **V**: Completely Weathered
- **VI**: Residual/Soil

FRACTURE ASPERITIES
- **RI**: Rough and Irregular
- **RU**: Rough and Undulating

ROCK MASS QUALITY
- **E**: Excellent
- **G**: Good
- **Fa**: Fair
- **P**: Poor
- **VP**: Very Poor

- **TCR:** Total Core Recovery Ratio
- **RQD:** Rock Quality Designation
- **RMR:** Rock Mass Rating after Bieniawski (1989)

PROJECT: PROPOSED BONDENI ESTATE, NAKURU TOWN	TERRACONSULT KENYA LIMITED	ELEVATION (m)	1805
LOCATION: NAKURU COUNTY		COORDINATES (UTM-WGS84)	E 0174760 ZONE 37 M
CLIENT: NATIONAL HOUSING CORPORATION.			N 9966920
		DATE(S)	START 22/03/19
			END 24/03/19
	BOREHOLE LOG	**Sheet No:** 2 of 2	
File No: 3-19-16	**Logged By:** Winnie Munene	**Checked By:** Dr. Issa Ismail	
Drilling Method: Rotary	**Drill Bit Type:** 86-101mm Diamond	**Borehole No:** 103	
Drill Rig Type: GY 150T	**Drilled By:** Kelvin Oduor	**Depth:** 25.00 m	
Apparent Depth of Ground Water: 8.100 m		**Inclination From Vertical:** 0°	

Depth (m)	ROCK CORE: Run (m)	TCR (%)	RQD (%)	RMR (RQD)	GRAPHIC LOG	MATERIAL DESCRIPTION	Weathering Grade	RMR (Weathering Grade)	Fracture Asperities	Fracture Frequency	Rock Mass Quality	SPT (N-Value)
13	1.5	23	0	3		Characterised by completely decomposed section.	IV	1	RI	mpos ed	VP	
14	1.5	21	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Deco mpos ed	VP	
15												
16	1.5	14	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Deco mpos ed	VP	
17	1.5	20	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Deco mpos ed	VP	
18												
19	1.5	15	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Deco mpos ed	VP	
20	1.5	23	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	Deco mpos ed	VP	
21												
22	1.5	33	0	3		Pale brown, moderately weathered, fine grained, moderately hard volcaniclastic deposits.	III	3	RI	Deco mpos ed	VP	
23	1.5	23	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	>20	VP	
24												
25	1	20	0	3		Pale brown, fine grained, moderately soft, highly weathered TUFF. Characterised by completely decomposed section.	IV	1	RI	>20	VP	

WEATHERING GRADES
- **I**: Fresh & Hard
- **II**: Slightly Weathered
- **III**: Moderately Weathered
- **IV**: Highly Weathered
- **V**: Completely Weathered
- **VI**: Residual/Soil

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ROCK MASS QUALITY
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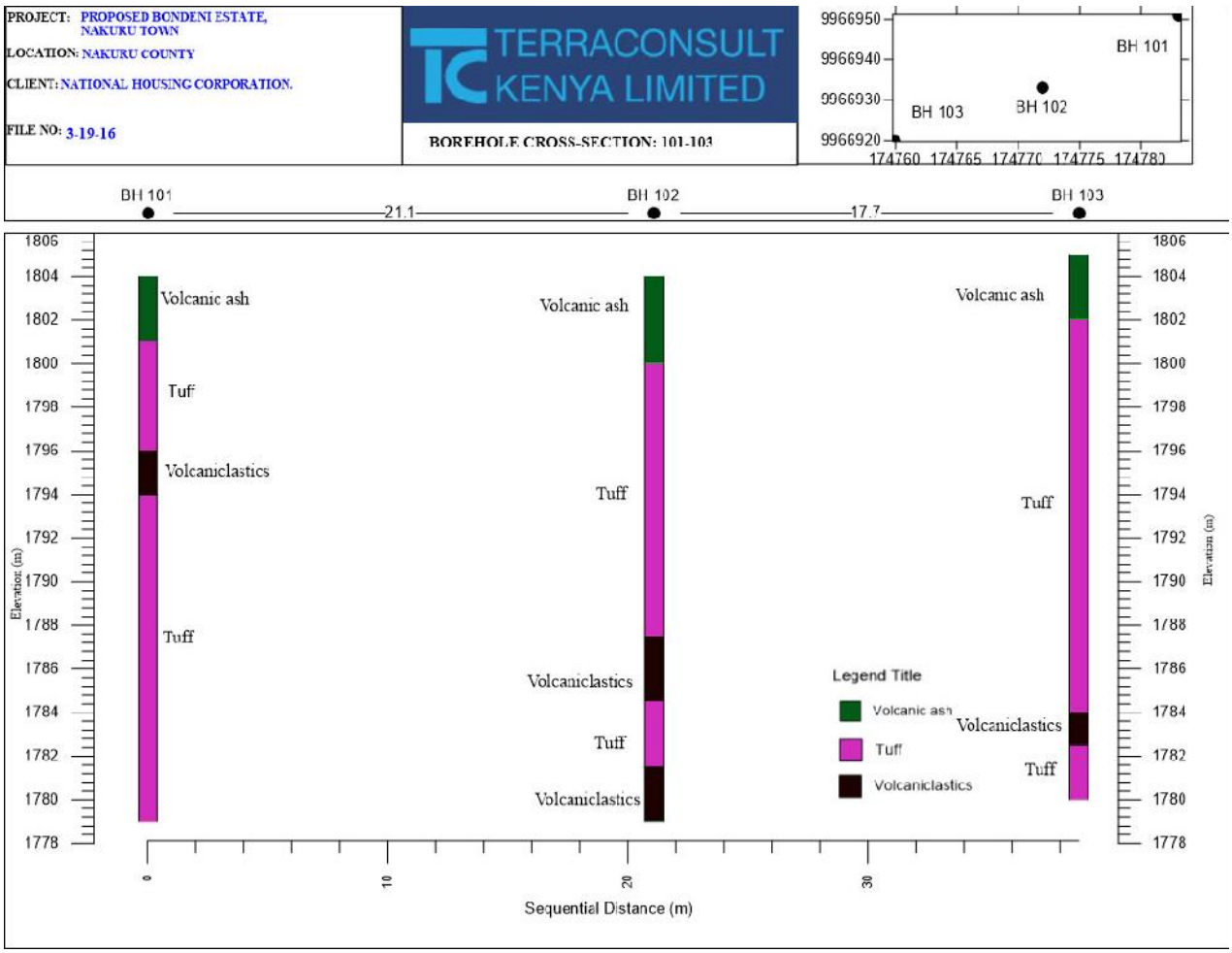
- **TCR:** Total Core Recovery Ratio
- **RQD:** Rock Quality Designation
- **RMR:** Rock Mass Rating after Bieniawski (1989)


PROJECT: PROPOSED BONDENI ESTATE, NAKURU TOWN
LOCATION: NAKURU COUNTY
CLIENT: NATIONAL HOUSING CORPORATION.
FILE NO: 3-19-16
TERRACONSULT KENYA LIMITED
BOREHOLE CROSS-SECTION: 101-103
9966950
9966940
9966930
9966920
174760 174765 174770 174775 174780
BH 101
BH 102
BH 103
BH 101
BH 102
BH 103
21.1
17.7
Volcanic ash
Tuff
Volcaniclastics
Tuff
Volcanic ash
Tuff
Volcaniclastics
Tuff
Volcaniclastics
Volcanic ash
Tuff
Volcaniclastics
Tuff
Legend Title
Volcanic ash
Tuff
Volcaniclastics
Elevation (m)
1806
1804
1802
1800
1798
1796
1794
1792
1790
1788
1786
1784
1782
1780
1778
0
10
20
30
Sequential Distance (m)

8. APPENDIX B-Sample Photographs

DRY SAMPLES

Borehole 101: 8.00-25.00m

Borehole 102: 6.00-25.00m

Borehole 103: 10.50-25.00m

WET SAMPLES

Borehole 101: 8.00-25.00m

Borehole 102: 6.00-25.00m

Borehole 103: 10.50-25.00m

Figure B-1 Topographic map indicating site location

9. APPENDIX C- Laboratory Results

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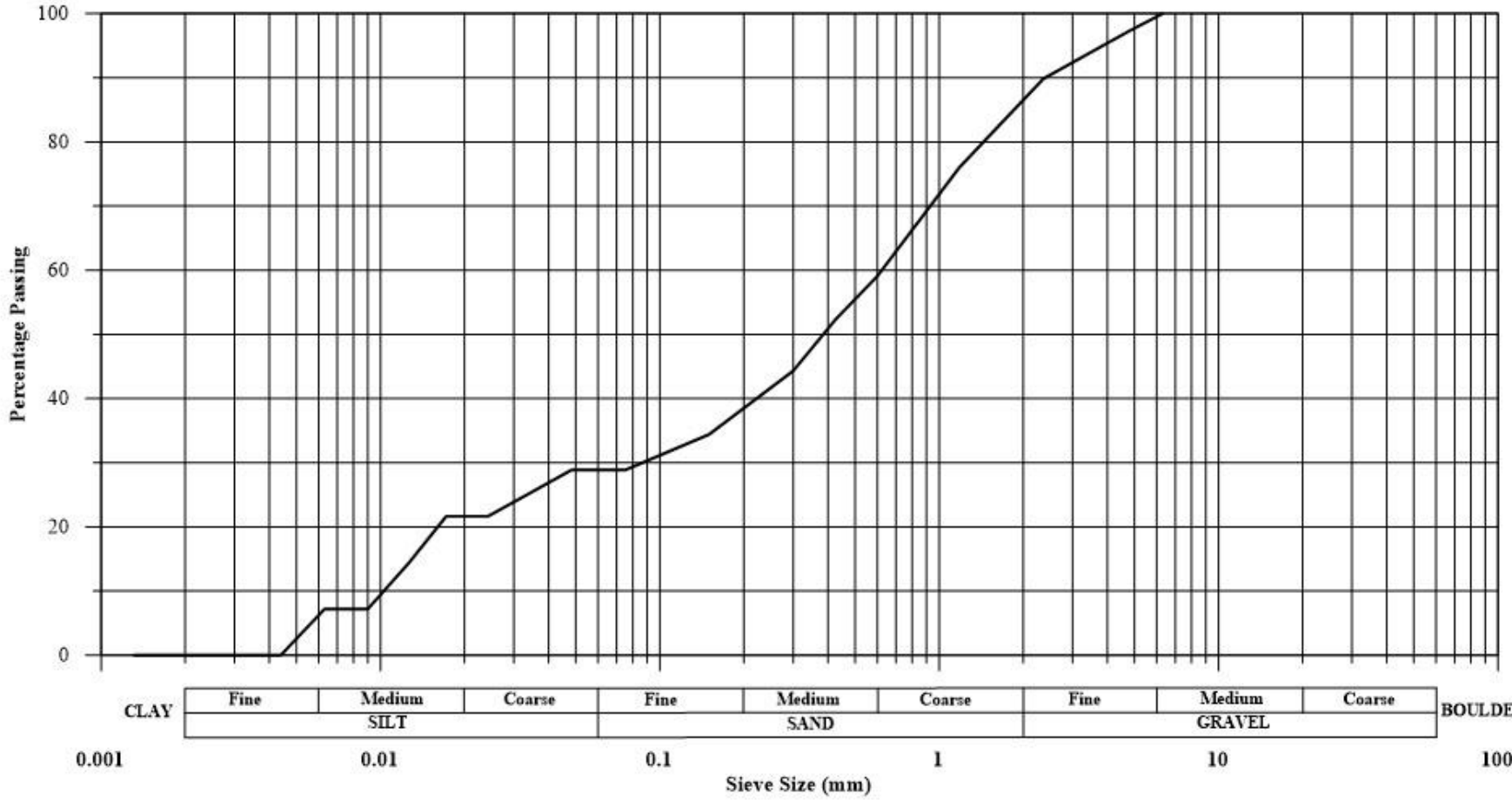
GEOISSA ENGINEERS LTD

Consulting Engineers & Material Testing Laboratories

PARTICLE SIZE ANALYSIS

File No. : 3-19-16
Project : PROPOSED BONDENI ESTATE - NAKURU
Client : NATIONAL HOUSING CORPORATION

Borehole No. : BH 101
Depth (m): 3.0 to 4.5
Fines: 53.60 %



Date : 05-04-2019 Tested by : CHRISTINE CHUMEK Reported by : CLEMENT MURIITHI Checked by : DR. ISSA ISMAIL

Likoni Lane
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GEOISSA ENGINEERS LTD

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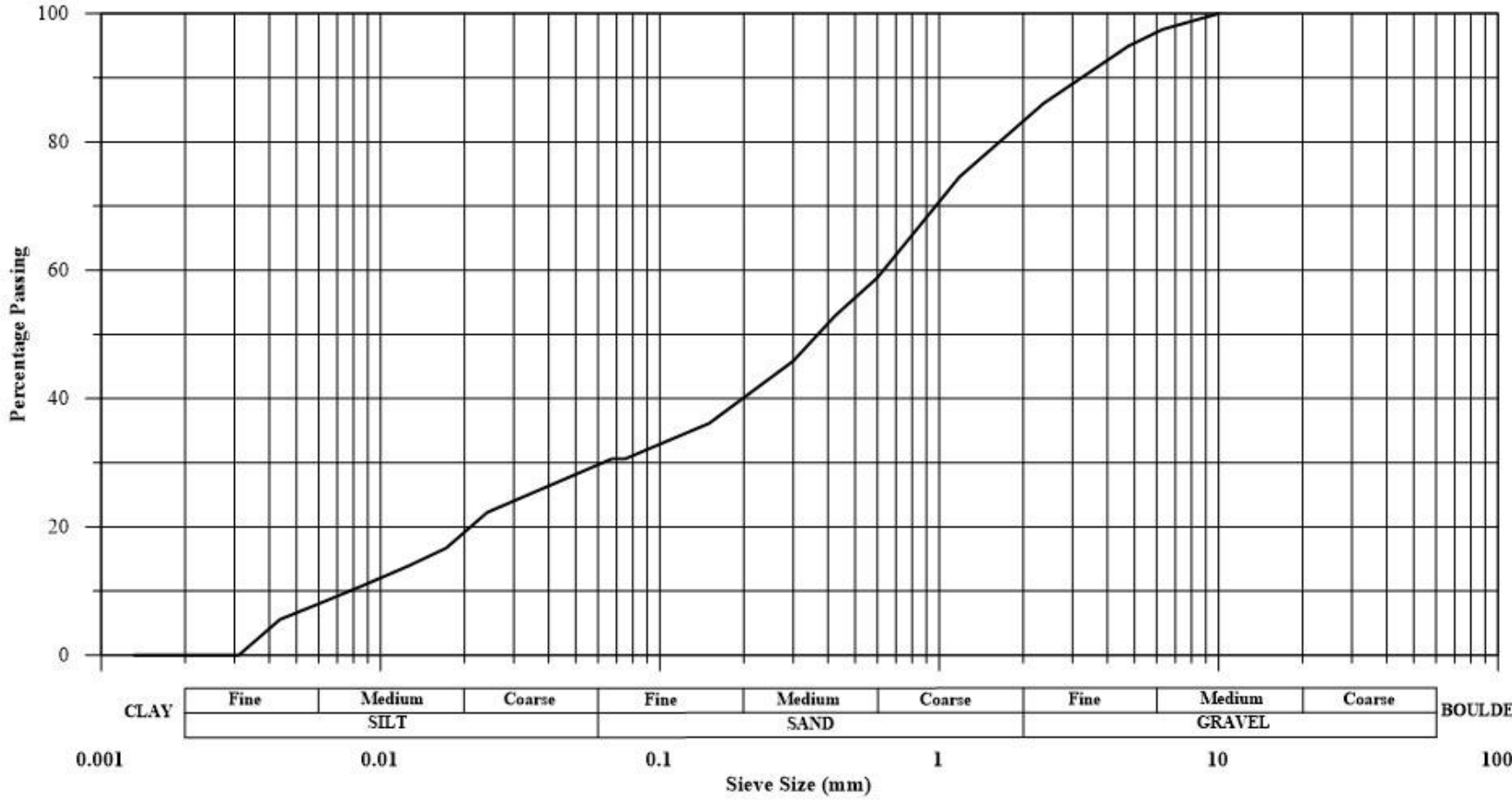
PARTICLE SIZE ANALYSIS

File No. : 3-19-16
Project : PROPOSED BONDENI ESTATE - NAKURU
Client : NATIONAL HOUSING CORPORATION

Borehole No. : BH 102
Depth (m): 2.0 to 4.0
Fines: 30.60 %



Date : 05-04-2019 Tested by : CHRISTINE CHUMEK Reported by : CLEMENT MURIITHI Checked by : DR. ISSA ISMAIL

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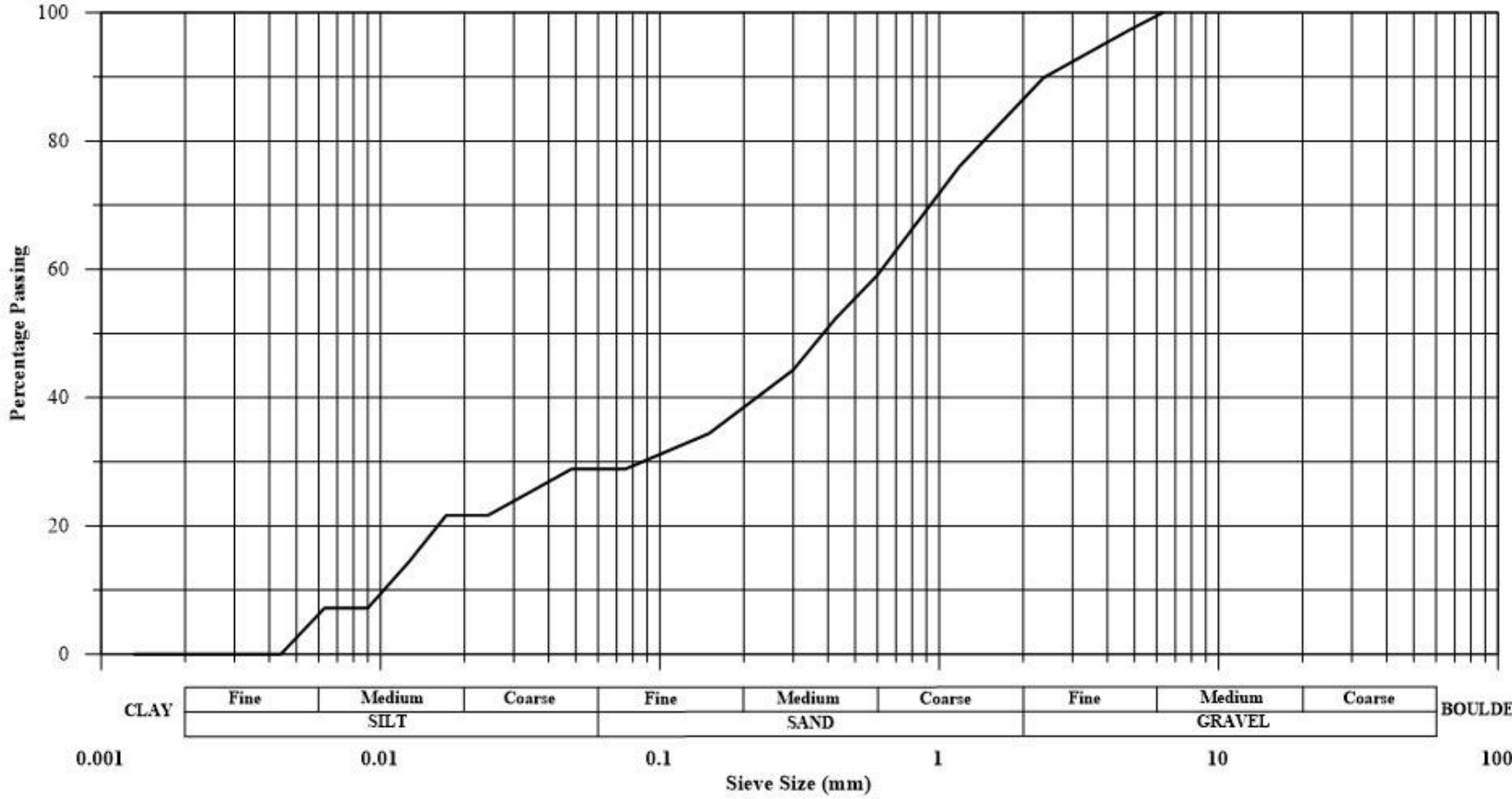
PARTICLE SIZE ANALYSIS

File No. : 3-19-16
Project : PROPOSED BONDENI ESTATE - NAKURU
Client : NATIONAL HOUSING CORPORATION

Borehole No. : BH 103
Depth (m): 0.0 to 1.5
Fines: 28.84 %



Date : 05-04-2019 Tested by : CHRISTINE CHUMEK Reported by : CLEMENT MURIITHI Checked by : DR. ISSA ISMAIL

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LIQUID LIMIT (CONE PENETROMETER) AND PLASTIC LIMIT TEST RESULTS

Client: **NATIONAL HOUSING CORPORATION** Date tested: 5-Apr-2019

Project: **PROPOSED BONDENI ESTATE-NAKURU**

Sample No. : **BH 101 (3.0-4.5)M, BH 102 (2.0-4.0)M, BH 103 (0.0-1.5)M**

Test Method: BS1377-2: 1990

LIQUID LIMIT

TEST NUMBER	1	2	3	
Cone penetration (mm)				
Container No.				
Container weight (gm)				
Wet soil + container (gm)				
Wet soil (gm). W_w				
Dry soil + container (gm)				
Dry soil (gm), W_d				
Moisture loss (gm), $W_w - W_d$				
Moisture content (%), $(W_w - W_d)/W_d$				

PLASTIC LIMIT:

TEST NUMBER	1	2
Container No.		
Container weight (gm)		
Wet soil + container (gm)		
Wet soil (gm), *Ww*		
Dry soil + container (gm)		
Dry soil (gm), *Wd*		
Moisture loss (gm), *Ww - Wd*		
Moisture content (%), *(Ww - Wd)/Wd*		
Average moisture content (%)		

NON PLASTIC

SHRINKAGE LIMIT:

SAMPLE DESCRIPTION		
Initial Length, L_o	mm	
Oven-dried Length, L_D	mm	
Clause 6.5.5 Linear Shrinkage = $\left(1 - \frac{L_D}{L_O}\right) x\ 100$	%	

SUMMARY:

Moisture Content at 20mm Penetration (%)	
Plastic Limit (%)	
Plasticity Index, PI = LL - PL	

PI	DESCRIPTION
0	Non-plastic
1 - 5	Slightly plastic
5 - 10	Low plasticity
10 - 20	Medium plasticity
20 - 40	High plasticity
> 40	Very high plasticity

Tested by: **Checked by:**

GRACE MAINA DR. ISSA ISMAIL

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ONE DIMENSIONAL CONSOLIDATION TEST

CLIENT: **NATIONAL HOUSING CORPORATION**
PROJECT: **PROPOSED BONDENI ESTATE**
Sample: **BH 103 (1.5-3.0)M**
Test date: **25-Apr-19**
Specification **According to BS 1377:1990.**

DIA OF RING	50.4	mm	HEIGHT OF RING	20.3	mm	AREA (A)	19.953	cm²

STAGE - AFTER TEST

MEASURED THICKNESS OF SPECIMEN (H1)		20.3	mm
WET SPECIMEN		83.49	g
MASS OF RING + TRAY + SPECIMEN		1609.3	g
MASS OF RING		59.93	g
MASS OF TRAY		1474.2	g
MASS OF DRY SPECIMEN (ms)		65.54	g
MASS OF MOISTURE		17.95	g
MOISTURE CONTENT (m)		35.0	%
BULK DENSITY (ρ)		1.86	g/cm³
DRY DENSITY (ρd)		1.38	g/cm³
INITIAL VOID RATIO (e_o)		0.96	
DEGREE OF SATURATION (Sr) m /(ρw/ρd - 1/Gs)		98.1	%
DENSITY OF SOIL PARTICLES ASSUMED Gs ρw		2.7	g/cm³
HEIGHT OF SOIL PARTICLES (H0) (ms x 1000)/(Gs ρw x A)		10.3	mm

APPLIED PRESSURE	TOTAL DEFLECTION D	THICKNESS OF SPECIMEN,H (H1-D)	PERCENTAGE THICKNESS H/H1 X 100	HEIGHT OF VOIDS (H-H0)	VOIDS RATIO H-H0/H0
kN/m²	mm	mm		mm	
0	0	20.30	100.00	9.96	0.963
25	0.907	19.39	95.53	9.05	0.875
50	0.066	19.33	95.21	8.98	0.869
100	0.207	19.12	94.19	8.78	0.849
200	0.34	18.78	92.51	8.44	0.816
FLOODED 200	0.016	18.76	92.43	8.42	0.814
400	0.46	18.30	90.17	7.96	0.770

Tested by : CLEMENT MURIITHI **Reported by :** CLEMENT MURIITHI **Checked by :** DR. ISSA ISMAIL

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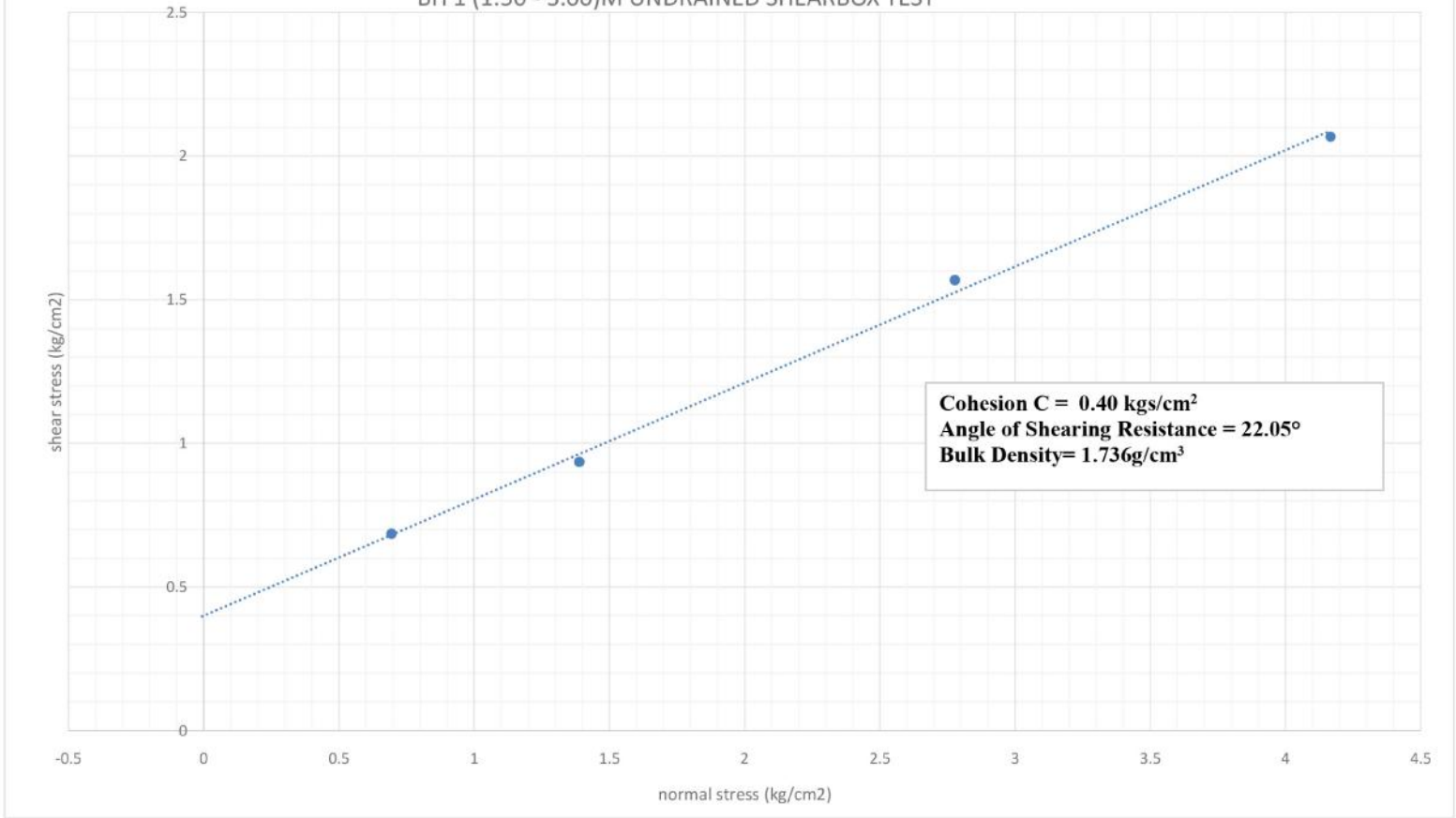
NAKURU NATIONAL HOUSING
BH 1 (1.50 - 3.00)M UNDRAINED SHEARBOX TEST



TESTED BY: JUMA

TEST DATE: 12-04-19

CHECKED BY: DR. ISSA ISMAIL

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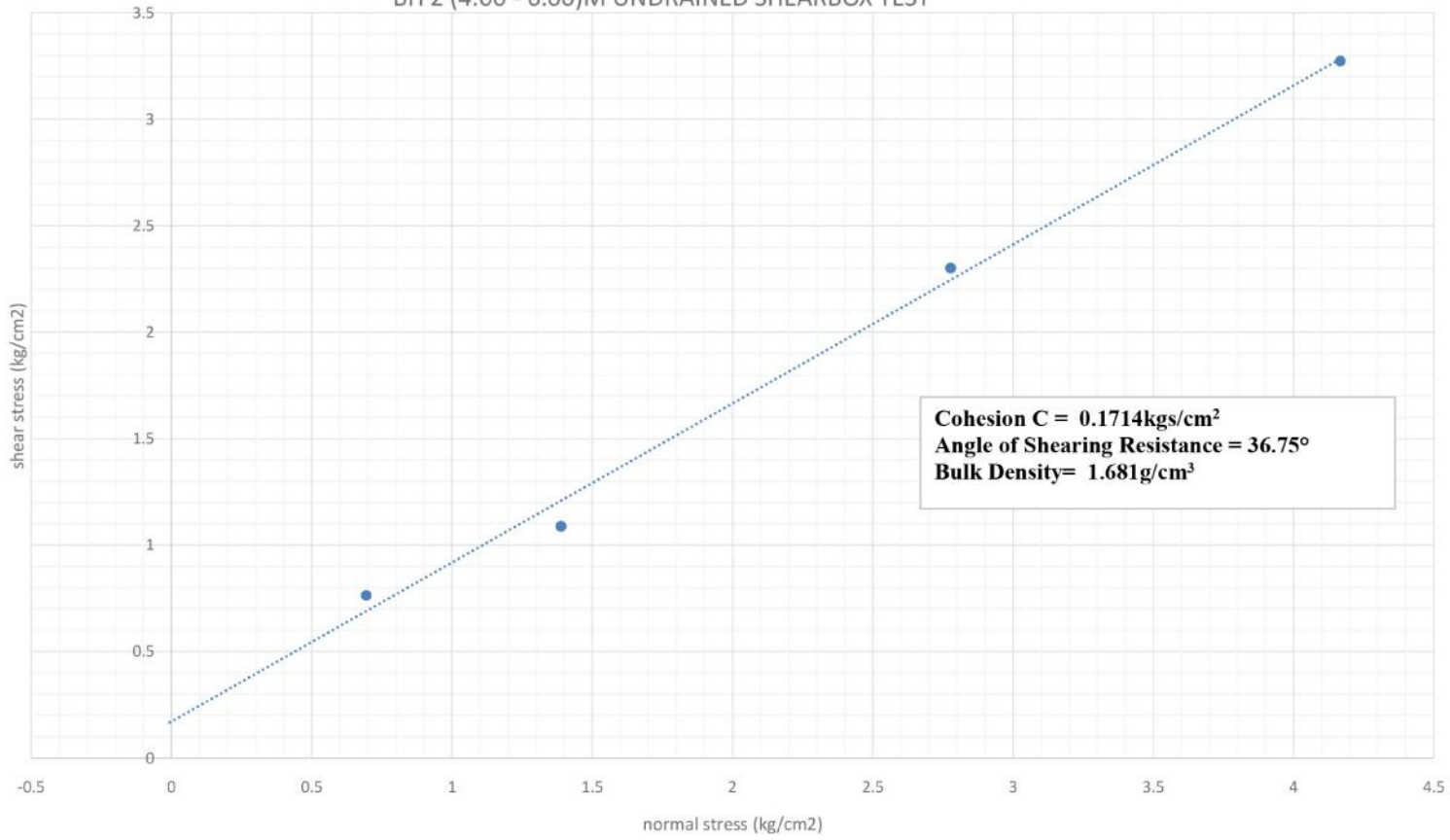
NAKURU NATIONAL HOUSING
BH 2 (4.00 - 6.00)M UNDRAINED SHEARBOX TEST



TESTED BY: JUMA

TEST DATE: 12-04-19

CHECKED BY: DR. ISSA ISMAIL

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POINT LOAD TEST

File No. : 3-19-16
Project : PROPOSED BONDENI ESTATE
Client : NATIONAL HOUSING CORPORATION
Location NAKURU

Standard : ASTM D5731
Date received : 25/3/19
Date tested : 3/4/19

Sample No.	Borehole No.	Depth (m) From	Depth (m) To	Field Index Strength	Moisture	Test Type	Failure Type	L_d, L_a or D (mm)	D_d, W_s or W (mm)	Density (Kg/m^3)	De^2 (mm^2)	De (mm^2)	P (kN)	P/D_d^2 (MPa)	P/De^2 (MPa)	$Is_{(50)}$ (MPa)	RMR ($Is_{(50)}$)	Estimated UCS $Is_{(50)}$*25	Safe Bearing Capacity (Mpa)	Remarks RMR $Is_{(50)}$
S1	BH102	10.00	10.10	MW	D	A	SP	68	81	1198	7012.09	83.74	1.200	-	0.17	0.22	2	5.40	0.81	Moderately Weak
S2	BH102	10.50	10.80	MW	D	A	SP	59.6	82	1354	6221.77	78.88	1.400	-	0.23	0.28	2	6.91	1.04	Moderately Weak
S3	BH103	10.50	10.60	W	D	A	SP	65.5	74.2	1303	6187.27	78.66	0.500	-	0.08	0.10	1	2.48	0.37	Weak

KEY: Symbol "-" means "not applicable" or "does not meet criteria"

Moisture
D- Dry
M- Moist
W- Wet

Field Index Strength
EW- Extremely Weak
W- Weak
MW- Moderately Weak
MS- Moderately Strong
S- Strong
VS- Very Strong
ES- Extremely Strong

Test Type
D- Diametral
A- Axial
L- Lump

Sample Dimensions
L_d - Height of Diametral Sample
L_a - Height of Axial sample
D_d- Diameter of Diametral Sample
D- Distance between Platen Contacts for Lump Sample
W_s- Diameter of Axial Sample
W- Smallest Specimen Width for Lump Sample

Failure Type
AF (Oblique/Parallel)- Failures along foliations when foliations are inclined /parallel
SP- Failure along single plane containing line of loading
TP- Triple Plane: Failure along three extensional planes
S - Shear Failure

RMR
RMR- Rock mass rating system (Bieniawski, 1989)

$Is_{(50)}$- Point load strength index for the standard core size of 50mm diameter

P- Load

Tested by : CLEMENT MURIITHI **Reported** CLEMENT MURIITHI **Checked by :** DR. ISSA ISMAIL

10. APPENDIX D-Relevant Literature

SAMPLING METHOD

SS	split spoon
ST	Shelby tube
AS	auger sample
WS	wash sample
RC	rock core
WH	weight of hammer
PH	pressure, hydraulic

PENETRATION RESISTANCE

Standard Penetration Test (SPT) resistance ('N' values) is defined as the number of blows by a hammer weighing 63.6 kg (140 lb.) falling freely for a distance of 0.76 m (30 in.) required to advance a standard 50 mm (2 in.) diameter split spoon sampler for a distance of 0.3 m (12 in.).

Dynamic Cone Test (DCT) resistance is defined as the number of blows by a hammer weighing 63.6 kg (140 lb.) falling freely for a distance of 0.76 m (30 in.) required to advance a conical steel point of 50 mm (2 in.) diameter and with 60° sides on 'A' size drill rods for a distance of 0.3 m (12 in.).

SOIL DESCRIPTION - COHESIONLESS SOILS

Relative Density	'N' value
very loose	< 4
loose	4 - 10
compact	10 - 30
dense	30 - 50
very dense	> 50

SOIL DESCRIPTION - COHESIVE SOILS

Consistency	Undrained Shear Strength, kPa	'N' value
very soft	< 12	< 2
soft	12 - 25	2 - 4
firm	25 - 50	4 - 8
stiff	50 - 100	8 - 16
very stiff	100 - 200	16 - 32
hard	> 200	> 30

SOIL COMPOSITION

	% by weight
'trace' (e.g. trace silt)	< 10
'some' (e.g. some gravel)	10 - 20
adjective (e.g. sandy)	20 - 35
'and' (e.g. sand and gravel)	35 - 50

TESTS, SYMBOLS

MH	mechanical sieve and hydrometer analysis
w, w_c	water content
w_l	liquid limit
w_p	plastic limit
I_p	plasticity index
k	coefficient of permeability
γ	soil unit weight, bulk
ϕ'	angle of internal friction
c'	cohesion shear strength
C_c	compression index

GENERAL INFORMATION, LIMITATIONS

The conclusions and recommendations provided in this report are based on the factual information obtained from the boreholes and/or test pits. Subsurface conditions between the test holes may vary.

The engineering interpretation and report recommendations are given only for the specific project detailed within, and only for the original client. Any third party decision, reliance, or use of this report is the sole and exclusive responsibility of such third party. The number and siting of boreholes and/or test pits may not be sufficient to determine all factors required for different purposes.

Table D-1 Soil and Insitu Test Description

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

PARAMETER			Range of values // ratings						
1	Strength of intact rock material	Point-load strength index	> 10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range uniaxial compr. strength is preferred		
		Uniaxial com-pressive strength	> 250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
		RATING	**15**	**12**	**7**	**4**	**2**	**1**	**0**
2	Drill core quality RQD		90 - 100%	75 - 90%	50 - 75%	25 - 50%	< 25%		
		RATING	**20**	**17**	**13**	**8**	**5**		
3	Spacing of discontinuities		> 2 m	0.6 - 2 m	200 - 600 mm	60 - 200 mm	< 60 mm		
		RATING	**20**	**15**	**10**	**8**	**5**		
4	Condition of discon-tinuities	Length, persistence	< 1 m	1 - 3 m	3 - 10 m	10 - 20 m	> 20 m		
		Rating	**6**	**4**	**2**	**1**	**0**		
		Separation	none	< 0.1 mm	0.1 - 1 mm	1 - 5 mm	> 5 mm		
		Rating	**6**	**5**	**4**	**1**	**0**		
		Roughness	very rough	rough	slightly rough	smooth	slickensided		
		Rating	**6**	**5**	**3**	**1**	**0**		
		Infilling (gouge)	none	Hard filling		Soft filling			
			-	< 5 mm	> 5 mm	< 5 mm	> 5 mm		
		Rating	**6**	**4**	**2**	**2**	**0**		
		Weathering	unweathered	slightly w.	moderately w.	highly w.	decomposed		
		Rating	**6**	**5**	**3**	**1**	**0**		
5	Ground water	Inflow per 10 m tunnel length	none	< 10 litres/min	10 - 25 litres/min	25 - 125 litres/min	> 125 litres /min		
		$p_w / \sigma 1$	0	0 - 0.1	0.1 - 0.2	0.2 - 0.5	> 0.5		
		General conditions	completely dry	damp	wet	dripping	flowing		
		RATING	**15**	**10**	**7**	**4**	**0**		

p_w = joint water pressure; $\sigma 1$ = major principal stress

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS

		Very favourable	Favourable	Fair	Unfavourable	Very unfavourable
RATINGS	Tunnels	**0**	**-2**	**-5**	**-10**	**-12**
	Foundations	**0**	**-2**	**-7**	**-15**	**-25**
	Slopes	**0**	**-5**	**-25**	**-50**	**-60**

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100 - 81	80 - 61	60 - 41	40 - 21	< 20
Class No.	I	II	III	IV	V
Description	VERY GOOD	GOOD	FAIR	POOR	VERY POOR

D. MEANING OF ROCK MASS CLASSES

Class No.	I	II	III	IV	V
Average stand-up time	10 years for 15 m span	6 months for 8 m span	1 week for 5 m span	10 hours for 2.5 m span	30 minutes for 1 m span
Cohesion of the rock mass	> 400 kPa	300 - 400 kPa	200 - 300 kPa	100 - 200 kPa	< 100 kPa
Friction angle of the rock mass	< 45°	35 - 45°	25 - 35°	15 - 25°	< 15°

Table D-2 Rock Mass Rating (RMR) after Bieniawski,1989

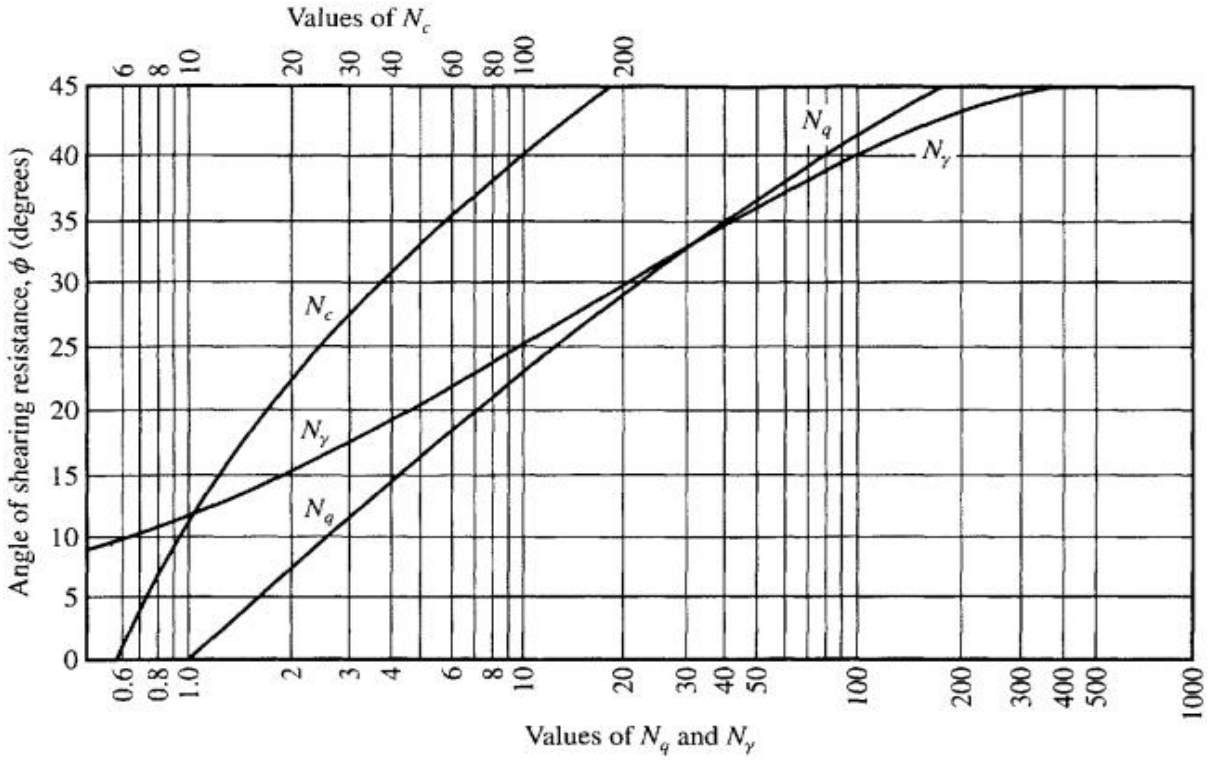

Figure D-1 Terzaghi' s bearing capacity factors

Figure D-2 Site Photo

11. REFERENCES

1. Bieniawski, Z. T. (1989). *Engineering Rock Mass Classification.* New York: John Wiley & Sons.
2. British Standards Institution. (1999). *BS 5930-1999 Code of Practice for Site Investigations.* London: British Standards Institution.
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