Appendix C

Geotechnical Investigation Report

NATPHARM MUTARE: GEOTECHNICAL INVESTIGATIONS SURVEY REPORT

CONSULTANT:
CIVILWORKS LABORATORY PRIVATE LIMITED,
No: 04 PLYMOUTH ROAD, SOUTHERTON, HARARE.

Tender number: NATCOMP 95/2017: R/40745

PROVISION OF CONSULTANCY SERVICES:- PROPOSED MUTARE WAREHOUSE

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Preamble: On the 13th of March 2017 Civilworks Laboratory Private Limited was awarded the NatPharm Mutare geotechnical investigations survey. NatPharm in conjunction with UNPD supervised by the Ministry of Public works and National housing proposes to build a new and much bigger pharmaceutical warehouse.

Database: This is a vacant stand proposed for a new structure. There are no previous buildings to get as builds from previous construction. No construction drawings or layouts are available yet.

Objectives of the survey: The objectives of the investigation were to complete a geotechnical survey of the site giving the following details:

i. The soil/rock profiles underneath, using a SPT bentonite slurry and manual excavated test pit.
ii. The engineering properties of the near founding level in-situ materials.
iii. Detailed foundation recommendations for the various structures.
iv. Comment on any perceived geotechnical problems which may affect the design and construction of the project.

Scope of works: The scope of work is as detailed in the RFP, in summary is as following:

a) Preferred type of foundation.
b) Recommended founding depth.
c) Bearing capacity of the soil at the recommended depth.
d) Recommended type of ground floor (hardcore) treatment.
e) Treatment of the bearing soils, i.e. (either cut to waste or cut to fill).
f) Suitability for use of excavated soils.
g) Depth of water table if so encountered, carry out pressure tests.
h) Any other information pertinent for foundation design.

Site Investigations: In the scope of works, three SPT bentonite slurry boreholes were to be done up to seven meters deep each at most. Three trial pits were dug in the proposed 10 000 m² vacant stand. Three samples from the trial pits were collected for foundation indicators testing.

Soil Investigations: For the trial pits and boreholes, soil tests to be carry out were:

1) DCP bentonite slurry for carrying out tests for determine founding depth and in-situ soil bearing capacity at recommended founding depth for the proposed structures as per standard procedure *(Part N: Materials Testing Standard Test Procedure (STP. 706)* as read with *CAS No: A43, part 2 1964).* This test was done in each borehole site before drilling.
2) Field vane shear tests up to seven meters deep. To determine the torque of the insitu material.
3) Static cone penetrometer up to seven meters deep. To determine whether there is need to recommend the use of piles.
4) To excavate three test pits for the reasons of
    a) soil profiling,
    b) soil geological origin identification,
    c) sampling of in-situ soil profiles,
    d) soil classification,
    e) foundation indicators tests including free swell and shrinkage limit
    f) etc.

Historical Review: - This is a vacant stand; there was no need to search for previous geotechnical investigations literature before commencement of this field work. This geotechnical report is the first for this site.

The regional geology of the area has been extracted from the 1: 1000 000, 7th Edition of the Zimbabwe Geological Map compiled by the Zimbabwe Geological Survey 1991.

Field Work: Civilworks Laboratory Private Limited undertook rotary core drilling of three boreholes to approximately seven meters depth each. Three trial pits were excavated and located in a triangular shape inside the vacant stand. For the SPT, the equipment is a 63.5kg hammer driving a 60° vented cone in one meter long extendable rods. For reducing skin friction, bentonite slurry is mixed in water and pumped in by a purpose made water pump.

Laboratory and office works: - From the samples recovered during the field work, laboratory tests were carried out as shown in results appendices 1 to 6 below. The following is the summary of RFP laboratory tests.

a) Foundation Indicator tests, including free swell and shrinkage limits tests
b) Proctor CBR tests
c) Permeability/percolation tests
d) Shear and consolidation tests
e) "Values and insitu soil bearing capacities in boreholes.

Three SPT boreholes site description: This site is located in Mutare General Hospital to its southern boundary. It's currently cultivated. There was no boreholes layout drawing or given coordinates or measurements to locate the exact positions. SPT positions were spaced in a triangular shape inside the 10 000 ㎡ vacant stand proposed for the construction of the pharmaceutical warehouse at approximately eighty meters apart in all three directions of a triangle.

Sites geology:-

The regional geology of urban Mutare specifically at the proposed site of the

pharmaceutical warehouse suggests that it is underlain by intrusive granitic sands. The residual soil exposed below the vacant stand, it appears to be primarily colluvium granitic sand. No parent rock was found within the seven meter depth except schist and decomposed granite. From natural ground level to average two hundred and fifty millimeter depth, it is humus granitic sand darkish in color. From two hundred fifty millimeter depth to seven hundred millimeter depth its creamy white pits sand. From seven hundred millimeter depth, there is a two hundred millimeter thick horizon of fine graded quartz to nine hundred millimeter depth from natural ground level. From nine hundred millimeter depth to four meters eight hundred centimeters, its schist, this consistently continuous is getting firmer and more compact with increase in depth. From four meters eight hundred to deeper than seven meters where SPT's ended its decomposed granite rock. The instu moisture content is averaging ten percent at average depth of four meters below ground level. The insitu density is 1590kg/m^3 at one and half meter depth from natural ground level. This confirms that it is granitic sand in geological origin.

Geological Hazard Report: As given by the Meteorological Office of Zimbabwe, the proposed site of the warehouse and Mutare as a whole, there is no known record of earthquakes or readable earth tremors from the Richter scale. Recorded, is the 21st September 2006 earthquake which happened at 22hrs 06 minutes and 12 seconds and read 5.6 on the Richter scale. And this one, did not only happen in Zimbabwe, but surround nations too. No floods or veld fires are known in this area of Zimbabwe.

Hydrology:-

The average annual rainfall in Victoria Falls urban is approximately 790.8mm. The driest month is July with at most 5.8mm precipitation occurs. The wettest month is December with an annual average of 167mm of rainfall. Most of the rains start in November and ends in March. It occurs in heavy isolated falls.

Slope Stability: - Mutare is a mountainous area, the natural drainage patterns observed allow easy surface infiltration from storm water and sheet wash. Vegetation is indigenous. No tree was observed with a girth of more than twenty centimeters measured from one

meter above ground level. No anthills noticed. In the vacant stand, there is a foot path where in some of its sections it has turned to be a gulley of approximately one meter three hundred centimeters deep.

Groundwater Conditions: No ground water was encountered in the three boreholes.

SPT Test method: The local specification used to determine the "N" value and the insitu soil bearing capacity is the Ministry of Transport and Infrastructure development Manual Part N (STP. 705) as read with CAS No: A43, part 2. The abbreviation for Ministry of Transport and Infrastructure Development is M.O.T & I.

SPT logging sheets: The method allows up to 25mm settlement.

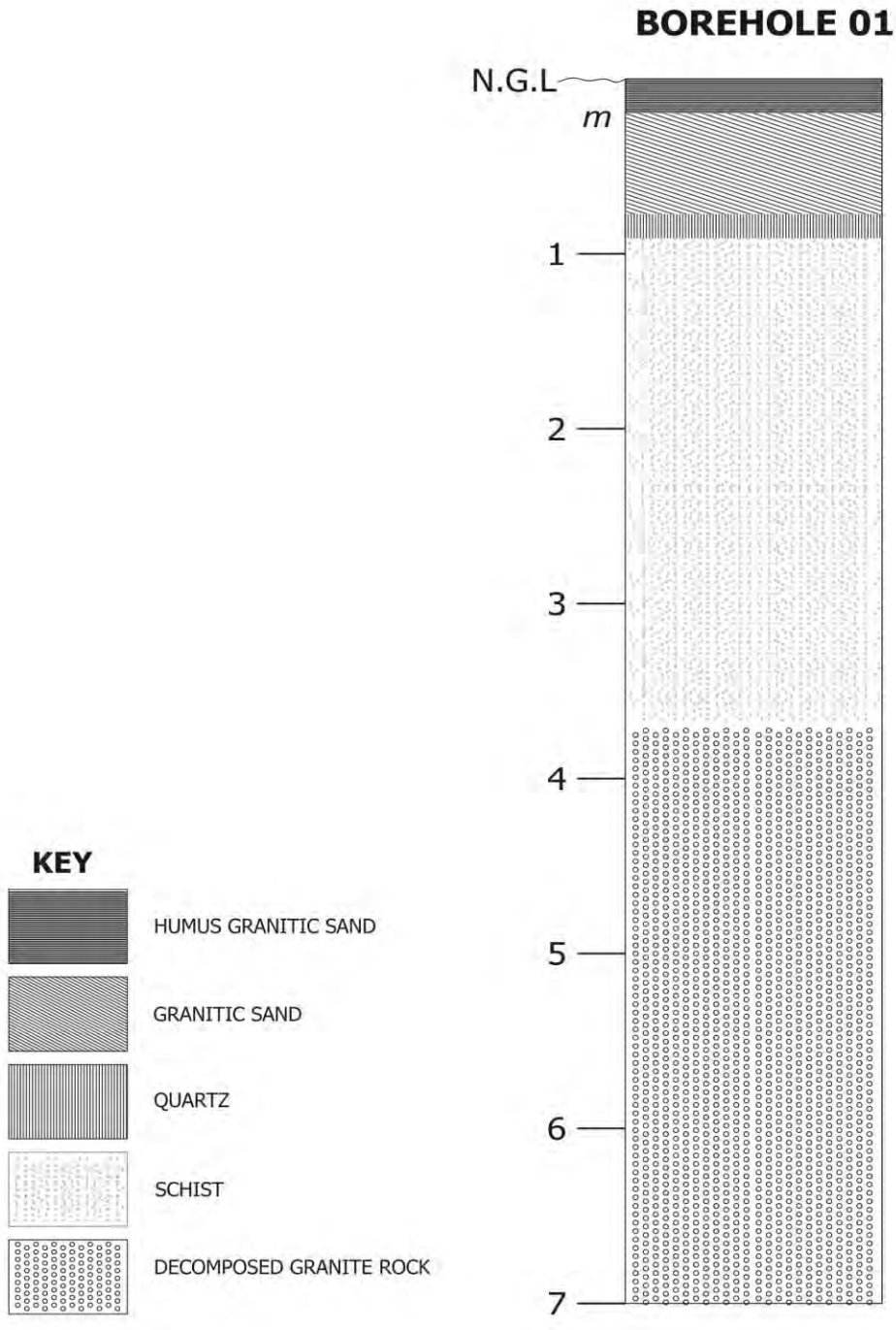
CIVILWORKS LABORATORY PRIVATE LIMITED GEOTECHNICAL INVESTIGATIONS – ROTARY CORE DRILLING						
PENETROMETER LOGGING SHEET						
CLIENT:- NatPharm		PROJECT:- Mutare warehouse			BORER:- Kasima Wisdom	
DRN No:-		BOREHOLE No:- 01 North			DATE:- 21/03/17	
CORE DETAILS		STANDARD PENETROMETER TEST				REMARKS
CUMMULATIVE *(m)*	GEOLOGICAL ORIGIN	SPLIT BARREL (Blows)		SPECIFICATION (kpa)		
		300	N Value	Terzaghi & Peck	M.O.T & I	
00.00→00.30		2	<14	<140	Soft	1 – Easily penetrated several centimeters by thumb due to humus. 2 - Danger of large settlement even under small loading.
00.30→00.60	Quartz	3			30	
00.60→00.90		5			75	

00.90→01.20	Schist	7	<14	<140	110	
01.20→01.50		5			75	1 - Seasonal water table begins. 2- "N" values decline due to presence of water.
01.50→01.80		5			75	
01.80→02.10		7			110	1 – "N"values continue to increase and firm with depth. 2 – Recommended founding depth is 2.5 meters. 3 – Recommended foundation type is pad (column/stub).
02.10→02.40		8	14		120	
02.40→02.70		9	15		130	
02.70→03.00		12	17	200	160	
03.00→03.30		13	18	240	170	
03.30→03.70		15	<22	240	200	
03.70→03.90	Decomposed Granitic rock.	Refusal	>50	650	> 1 000	Refusal or bouncing back of 63.5kg hammer as it reaches rock like material.
03.90→04.20						
04.20→04.50						
04.50→04.80						

Notes on "N" Values:

1) From zero to 2, its very soft insitu material easily penetrated several centimeters deep by a fist, e.g. clayey or humus soils.
2) From 2 to 4, it's soft, easily penetrated several inches deep by thumb, danger of large settlements even under small loads.
3) From 4 to 8, its medium soft/stiff insitu material can be penetrated several centimeters by thumb with moderate effort.
4) From 8 to 16, its stiff soils, readily indented by the thumb but penetrated only with effort.
5) From 16 to 30, it's very stiff insitu soils, readily intended by thumbnail.
6) From 30 and above, its hard insitu soil, indented only with difficulty by thumbnail.

Borehole No: 01 profile:



CIVILWORKS LABORATORY PRIVATE LIMITED

GEOTECHNICAL INVESTIGATIONS – ROTARY CORE DRILLING

PENETROMETER LOGGING SHEET

CLIENT:- NatPharm PROJECT:- Mutare warehouse DRILLER:- Zikhali Bekithemba

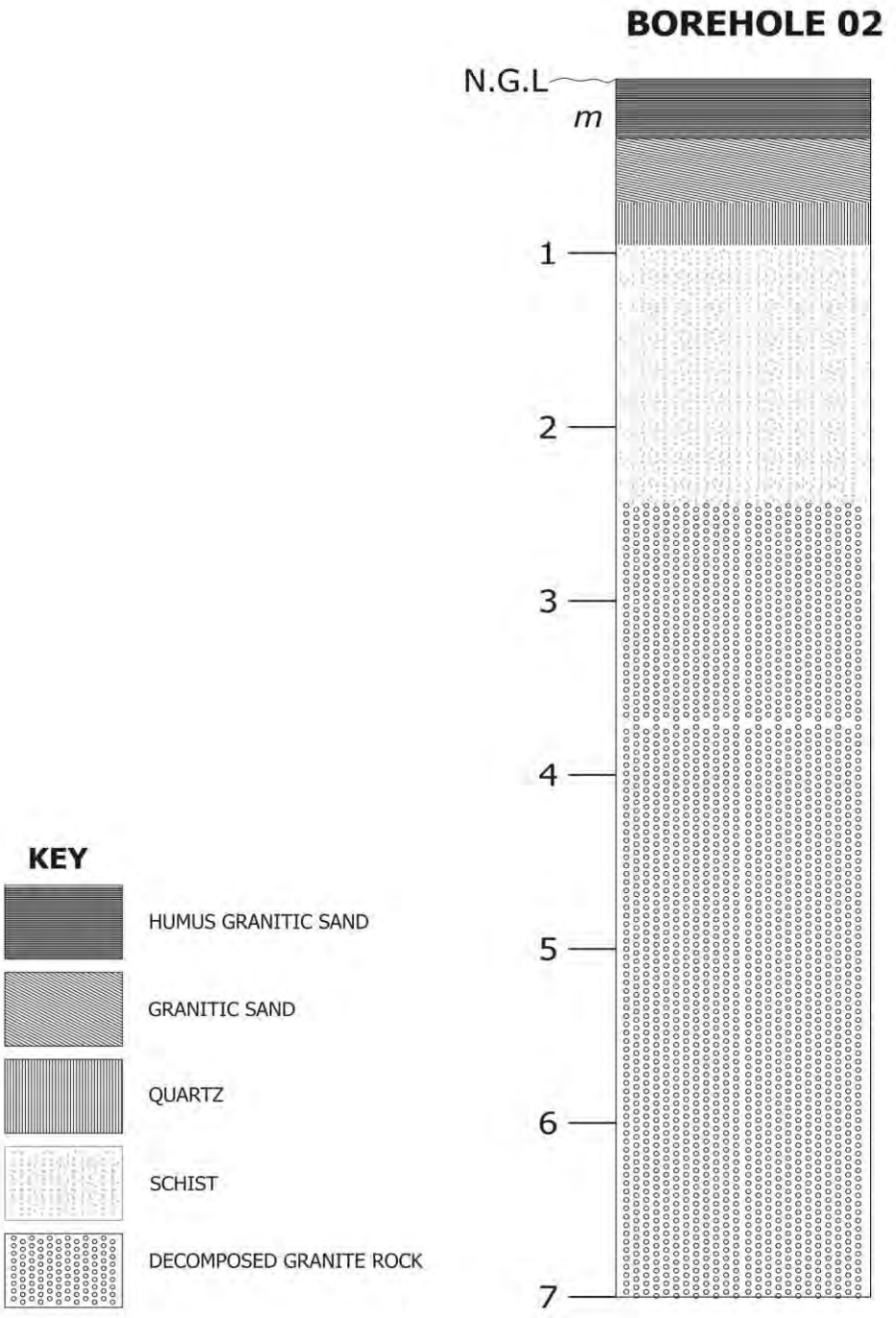
DRN No:- BOREHOLE No:- 02 South West DATE:- 22/03/17

CORE DETAILS		STANDARD PENETROMETER TEST				REMARKS
CUMMULATIVE (m)	GEOLOGICAL ORIGIN	SPLIT BARREL (Blows)		SPECIFICATION (kpa)		
		300	N Value	Terzaghi & Peck	M.O.T & I	
00.00→00.30		4	<14	< 140	60	Humus granitic overburden sand.
00.30→00.60		4				1 – Seasonal water table encountered as from 0.7 meter depth.
00.60→00.90	Quartz	5			80	
00.90→01.20	Schist	6			90	
01.20→01.50		10	16	200	150	1 – The recommended foundation type is pad (stub/column). 2 – The recommended founding depth is 1.5 meters.
01.50→01.80		13	<22	260	180	
01.80→02.10		17	<24	<300	230	
02.10→02.40		23	32	420	320	
02.40 → 02.70	Decomposed Granitic Sand.	Refusal	>50	650	> 1 000	

Notes on “N” Values:

1) From zero to 2, its very soft insitu material easily penetrated several centimeters deep by a fist, e.g. clayey or humus soils.
2) From 2 to 4, it's soft, easily penetrated several inches deep by thumb, danger of large settlements even under small loads.
3) From 4 to 8, its medium soft/stiff insitu material can be penetrated several centimeters by thumb with moderate effort.
4) From 8 to 16, its stiff soils, readily indented by the thumb but penetrated only with effort.
5) From 16 to 30, it's very stiff insitu soils, readily intended by thumbnail.
6) From 30 and above, its hard insitu soil, indented only with difficulty by thumbnail.

Borehole No: 02 profile



CIVILWORKS LABORATORY PRIVATE LIMITED

GEOTECHNICAL INVESTIGATIONS – ROTARY CORE DRILLING

PENETROMETER LOGGING SHEET

CLIENT:- NatPharm PROJECT:- Mutare warehouse DRILLER:- Banda Lovejoy

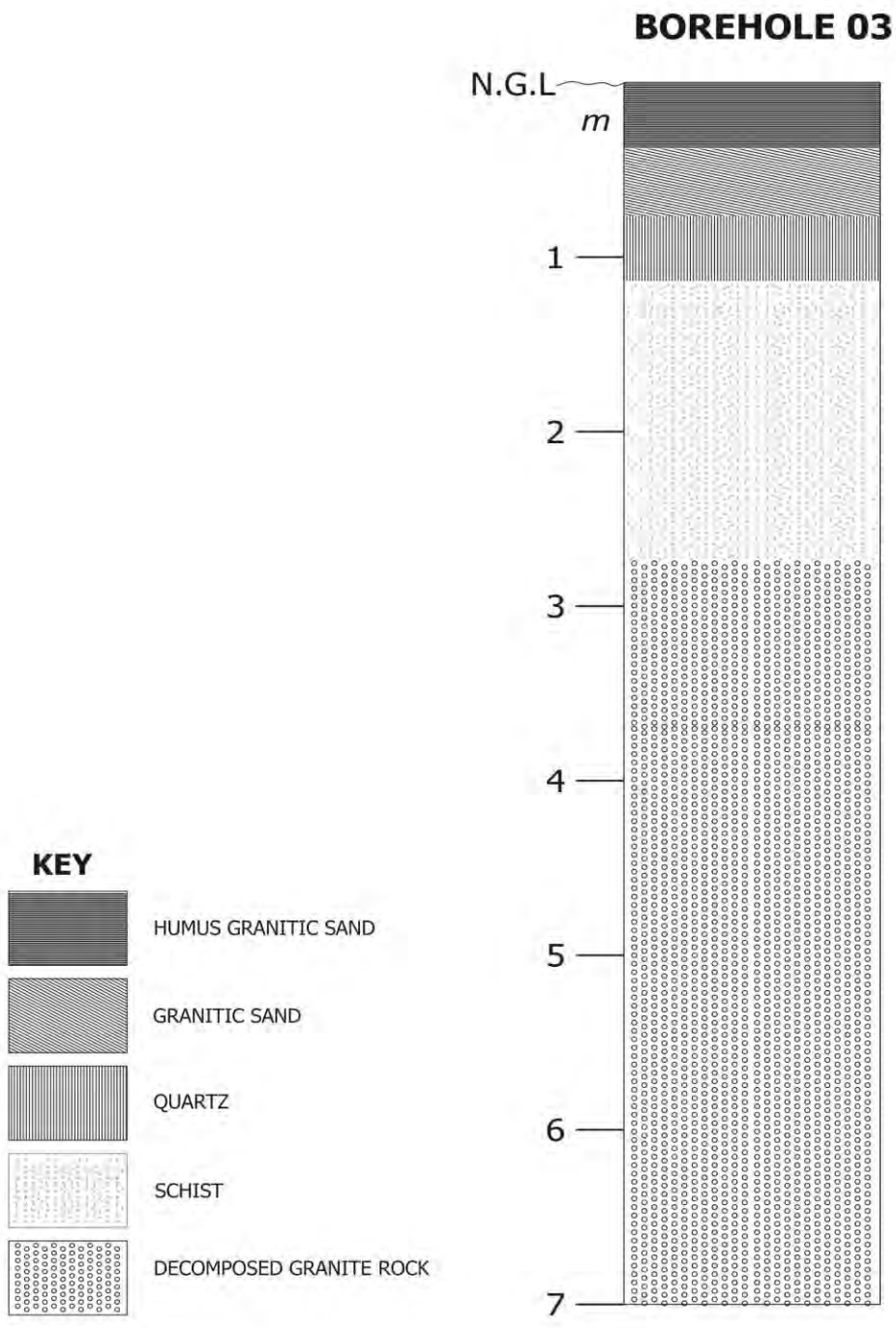
DRN No:- BOREHOLE No:- 03 South East DATE:- 20/03/17

CORE DETAILS		STANDARD PENETROMETER TEST				REMARKS
CUMMULATIVE *(m)*	GEOLOGICAL ORIGIN	SPLIT BARREL (Blows)		SPECIFICATION (kpa)		
		300	N Value	Terzaghi & Peck	M.O.T & I	
00.00→00.30	Granitic Sand	3	<14		30	Humus granitic overburden
00.30→00.60	Quartz	3		<140	30	
00.60→00.90		5			75	1 – Water table encountered. 2 – SPT's reduced by ingress of water.
00.90→01.20	Schist	7			110	
01.20→01.50		8	14		120	1- "N" values increase with increase in depth. 2- Recommended founding depth is 2.0 meters. 3- Recommended foundation type is pad (stub/column).
01.50→01.80		8			120	
01.80→02.10		9	15		130	
02.10→02.40		11	16	200	150	
02.40→02.70		16	22	260	210	
02.70→02.80		20	28	370	280	
02.80 → 07.00	Decomposed Granitic Sand.	Refusal	>50	650	> 1 000	1 – Penetration ceases. 2 – 63.5kg hammer bounces back.

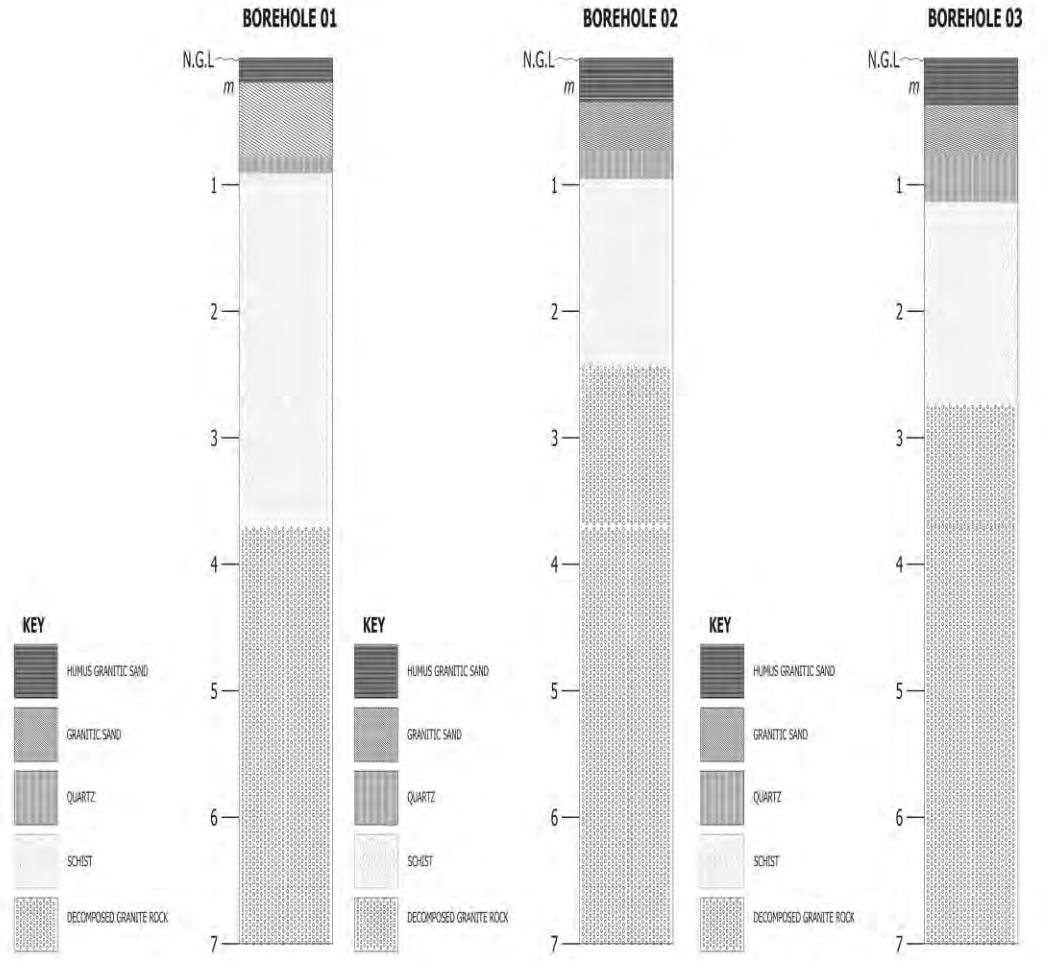
Notes on “N” Values:

0) From zero to 2, its very soft insitu material easily penetrated several centimeters deep by a fist, e.g. clayey or humus soils.
1) From 2 to 4, it’s soft, easily penetrated several inches deep by thumb, danger of large settlements even under small loads.
2) From 4 to 8, its medium soft/stiff insitu material can be penetrated several centimeters by thumb with moderate effort.
3) From 8 to 16, its stiff soils, readily indented by the thumb but penetrated only with effort.
4) From 16 to 30, it’s very stiff insitu soils, readily intended by thumbnail.
5) From 30 and above, its hard insitu soil, indented only with difficulty by thumbnail.

Borehole No: 03



Boreholes profiles summary:



Foundation indicators: Table No: 01

SUMARRY OF LABORATORY TESTS										
Hole No:	GEOLOGICAL ORIGIN	TEST CARRIED OUT								
		% P.I	% L.S	GM	% M.C	CBR Mod	Activity	Ic	Sg	Density kg/m^3
1	Quartz/Schist.	8	4	1.9	9.5	29	Nil	27	2.5	2210
2		11	6	1.4	10.3	21	Nil	19	2.1	2140
3		9	5	1.8	8.8	32	Nil	34	2.3	2260

Legend:

L/M means – low to medium activity

G.M. – grading modulus

L.S. - Linear shrinkage

CBR – California bearing ratio

M.C. – Moisture content

S.G. – Specific gravity.

P.I. – Plasticity index

I.C, - Coarseness Index

Summarized Insitu soil boreholes profiles: Table 02

Item	Geological Origin	"N" Value	Kpa	Recommended Structure category
0 - 2	Quartz/Schist.	<16	140	<150kpa (Medium loaded)
2 - 4		<24	230	<250kpa Heavily loaded)
4 - 6		>50		>750 kpa (Very heavily loaded)
6 - 8			> 1 000	

Table No: 04

Boreholes strata analyses						
Material Type	Layer Thickness (m)			Depth from Natural ground level (m)		
	Max	Avg	Min	Max	Min	Avg
Granitic Sand - Overburden	00.35	00.30	0.25	00.45	00.25	00.30
Granitic sand - Seam	00.45	00.40	00.35	00.70	00.25	00.60
Quartz	00.30	00.30	00.20	01.00	00.60	00.70
Schist	02.80	02.03	01.50	03.70	00.90	02.60
Decomposed Granitic Sand	-	-	-	-	-	-

Notes on table No: 04:

I. Table 01 given above gives the maximum, minimum and average depths to the top of the natural ground level and their layer thicknesses. This a comparison of the three boreholes done inside the vacant stand.

II. This is a profile from natural ground level in meters to approximately seven meters where SPT's ceased. This does not include the trial pits.

III. No underground services were exposed during the carrying out of the field tests.

Interpretive Report: The generalized soil profile for the three boreholes in the proposed warehouse site observed appears as follows.

1. The site is overlain by savanna grass and maize cultivation.
2. There are two gullies of at most twenty meters long and one half meters deep.
3. Overburden is averaging three hundred millimeters deep of humus granitic sand geological origin.
4. Seam it's of slightly plastic pit sand mixed with granitic sand. Its averaging four hundred millimeters thick and up to a depth of seven hundred millimeters from natural ground level.

5. A quartz layer of average two hundred millimeters follows beneath the granitic/pit sand layer. It's up to at most one meter from natural ground level.
6. Below quartz it's a horizon of schist which averages two and half meters thick and approximately up to three meters seven hundred centimeters from natural ground level. This is very moist schist.
7. Below schist is decomposed granite.
8. Imported material, it is colluvium granitic material from the close by mountains.
9. Indicator tests suggest that, the fine to medium coarse granitic sand exhibit nil heave potential. Granitic and forest sands do not bulk like Kalahari sand which needs pre-collapsing.
10. The plasticity index (Ip) of the insitu material tends to reduce from slightly plastic to non-plastic as depth increases. From natural ground level to approximately a meter deep, this is the upper horizon, composed of granitic sand. The approximately two hundred millimeter thick layer of the quartz is the one which has plasticity index of lower than the maximum allowable Ip of 12%. (Colto & ministry of Transport materials planning and testing manuals). (Refer to appendix 2 foundation indicator results).
11. Angle of repose: - From the drilling and the trial pits, the insitu granitic sand even due to its low plasticity content, it has cohesive mechanical properties, it does not collapses easily. The angle of repose is much lower than 15^0.
12. Decomposed granite is from three meter seven hundred centimeters below natural ground level.
13. Soft rock: - There was no soft rock encountered both from drilling and open pit excavations.
14. Parent rock: - No rock bed was encountered.

Boreholes water table: No permanent water table was encountered except for seasonal perched water table.

Proposed design parameters as from SPT profiles: Table 05

Table No: 2 – Design parameters		
Material Type	Allowable Bearing Capacity (Kpa)	TR 14 Classification
Colluvium Granitic Sand	100 (subject to precautions)	G8
Residual Granitic Sand	150:	G6
Quartz	>250	Processed hardcore gravel meeting G5 or better classification.
Soft Rock	>1 000	
Parent rock		

Design solutions:

Earthworks and terraces: - Due to the slope on the north western side of this site, it may be necessary to construct terraces or some kind of slope and erosion protection. There might be a need too to construct a catch water drain along the mountain slope. All terraces should be constructed from material which is classified as G7 or better and compacted in 150 mm layers to a minimum of 94% Mod AASHTO. In this regard, the in-situ colluvium material is not suitable for such use.

Notes on foundation:

1. Tree trunk diameter: - There are no trees that would need excavation therefore creating pits to be backfilled.
2. Roots wads: - No roots to be removed
3. Compaction/Shrinkage factor: - because of the absence of trees and roots, this has no effect. Trees have a compaction factor of 25 – 30%.
4. Swell factor: -The geological origin of the material at recommended founding depth its either schist or decomposed granite, these do not swell or bulge.

5. Drainage: - Removal of excess surface and subsurface water originating from rainfall is the principal purpose of drainage to this proposed site. The physical properties of granitic sand soils make drainage easier to design than heavy clayey soils. A catch water drain on the mountainside and wider covered u-drains around the proposed structure.

a) Capillarity rise in sandy soils is lower than heavy clayey soils. The soil profile in this whole construction zone has no impermeable layer existing near the foundation depth. The in-situ soil is likely to drain well under the hardcore.

b) Hydraulic conductivity: - that is the ability for in-situ soil to transmit water in itself or on its own. In less humus and low plasticity soils like the granitic sand on site, it ranges between 1 – 1 000 m/day, while in clayey soils like black cotton soils, it ranges between 0.001 – 1 m/day. However, perched water table was encountered in trial pits, conductivity is of less concern. As this is vacant stand is in a built up area. no sewer leakages were observed that can case underground contamination that can be carried by leach water and be deleterious to concrete.

6. Cut to waste overburden.

Proposed Structures Categories:-

Lightly loaded structures: (applied load not exceeding 100kpa)**:-** It is suggested that, structures imparting an applied load of less than 100kpa should be founded within the residual granitic sand. Due to the non-heave potential of the colluvium and to a lesser degree the upper residual granitic sand, these structures should be founded on non-reinforced or lightly reinforced strip footings. It's further recommended that brick force be included between every course up to the underside of the floor slab.

For these structures, it is further recommended that, at least 450 mm of inert granular fill of G7 or better, be placed in 150mm layers and compacted to 94% Mod AASHTO below the floor slab.

Medium loaded structures (applied load not exceeding 150kpa):- It is recommended that these structures be founded on a reinforced strip footing or raft foundation located within the residual Kalahari sand at between 1.5 meters to 2.5 meters below current natural ground level.

Where the internal floor slabs occurs above the colluvium soil, it is recommended that this material be removed and replaced with at least 600mm thickness of compacted inert granular G7 fill material 94% Mod AASHTO.

Heavily loaded structures (applied load not exceeding 250kpa):- It is recommended that these structures be founded on a pad foundation locate in the medium dense granitic sand at depths of approximately two meters.

Very Heavily loaded structures (applied load not exceeding 750kpa):- It is recommended that these structures be founded on a raft foundation locate in the dense decomposed granite at depths of around ten meters.

Construction problems: - There are no envisaged construction problems. Soft excavation of the granitic sand is expected. No blasting or removal with pneumatic tools is again envisaged. No deep excavation is expected. The excavated material is suitable use in selected layers. Should large quantities of backfill be required, this has to source from a commercial supplier.

Construction monitoring:

Excavation inspection: - It is recommended that all foundations be monitored and inspected by a competent person prior to placing any fresh cast in-situ concrete. This includes the excavation to founding depth.

Proposed Structures Hardcore Treatment: Table No: 06:-

SUBSTRUCTURE TREATMENT :			
Item	Structure Category	Kpa	Treatment
1	Lightly Loaded	<125	a) Founding depth without or residual granite sand. b) Light reinforced strip footing. c) Brick force at every course to below floor slab. d) Inert fill, in layers of 150mm compacted to 94% Mod AASHTO .
2	Medium Loaded	<180	i. Found within medium colluvium Granitic sand. ii. Raft or reinforced strip footings. iii. Cut to waste. Replace 450mm layer thickness and import inert fill, compacted to 94% Mod AASHTO .
3	Heavily Loaded	<300	i. Founded in dense coarse graded granitic sand. ii. Raft or pad foundation. iii. Cut to waste & replace with 600mm layer thickness & import inert fill. 150mm layers compacted to 94% Mod AASHTO .
4	Very Heavily Loaded	<750	i. Out of this scope.

Trial Pits: Three trial pits were excavated inside the vacant stand and equally spaced. Samples were collected in these trial pits and tested for foundation indicator tests. See the photos on appendix 8. The in-situ soil is darkish grey fine graded granitic overburden. It's approximately three hundred millimeters deep. Thereafter its pit sand mixed with granitic sand. Then a layer of quartz is below granitic sand. After quartz follows a schist horizon. Below schist its decomposed granite.

Table 07:

Table No: 07 – Trial pits excavation profiling data		
Test Hole No:	Depth (m)	In-situ material at base of test hole
TP 1 - 3	0.00 – 0.30	Darkish grey humus fine graded granitic sand.
	0.30 – 0.70	Granitic/pit sands
	0.70 – 0.90	Fine graded quartz
	0.90 – 3.70	Schist
	3.70 →	Decomposed granite.

Observations in trial pit:

a) Perched seasonal water table at approximately one meter below natural ground level.

Laboratory and Field tests results: All laboratory testing and field data results are attached as appendix one to six of this report. The report also includes the summarized analyses of the field and laboratory tests results in various topics above and below as a narration. For more accurate determination and classification purposes, particle size distribution, atterberg limits and CBR tests were carried out on representative disturbed samples of the various soil horizons. The tests methods are as listed in appendix 8 in the table of references.

Founding on rock:

No rock was found in the SPT tests of the three boreholes.

Foundation types recommended:

The recommended foundations type is pad (stub/column).

The average recommended founding depth for the proposed warehouse is two meters below the natural founding depth. The SPT logging sheets remark on each borehole suggested founding depth. The minimum recommended founding depth being two meters

and the maximum being two and half meters below natural ground level. The foundation type is a pad (stub/column). This can be stepped due to the gradient of the site. The average insitu soil bearing capacity at founding depth is 200kpa. The average insitu soil corrected SPT "N' value is 22.

Soil Permeability: Granitic sand is permeable as seen in the results below. Granitic sand is generally single sized graded with a high voids ratio.

Permeability Test Results: –

CRITERIA	Trial Pit:
Coefficient of permeability (K_t) mm/sec	0,00463
Drainage Characteristics	Good
Soil description	Granitic Sand

The above result is an average of the three tests done on excavated tests pits.

Appendix 3:- Shear tests

Tests were done on material excavated from trial pits numbers one and three.

Shear Test Results:

Pit No:	Test 1 (10kg)			Test 2 (15kg)			Test 3 (20kg)		
01	Normal Stress kN/m²	Shear Stress kN/m²	Tan ϴ Degrees	Normal Stress kN/m²	Shear Stress kN/m²	Tan ϴ Degrees	Normal Stress kN/m²	Shear Stress kN/m²	Tan ϴ Degrees
	384.7	311.71	27.26	523.30	339.13	24.43	671.09	482.57	22.33

Apparent cohesion (C) kN/m² 0

Angle of shearing resistance (Ø)° 24

Pit No	Test 1 (10kg)			Test 2 (15kg)			Test 3 (20kg)		
03	Normal Stress kN/m²	Shear Stress kN/m²	Tan ϴ Degrees	Normal Stress kN/m²	Shear Stress kN/m²	Tan ϴ Degrees	Normal Stress kN/m²	Shear Stress kN/m²	Tan ϴ Degrees
	401.20	306.86	29.72	497.66	359.52	23.84	635.48	434.17	19.04

Apparent cohesion (C) kN/m²	0
Angle of shearing resistance (Ø)°	21

Appendix 4 Free Swell Tests

Analyses of free swell results:-

Swell tests were carried out on samples of soil excavated from the trial pits. The general results show that, the insitu soil is non-plastic. No seasonal volumetric changes are expected.

Borehole no: 01

Original amount of soil in 100ml distilled water (1)	10ml
Amount of soil after standing for 24 hours (2)	11ml
% Free Swell : (2-1)*100/1	10.0

Borehole no: 02

Original amount of soil in 100ml distilled water (1)	10ml
Amount of soil after standing for 24 hours (2)	10ml
% Free Swell : (2-1)*100/1	00.0

Borehole no: 03

Original amount of soil in 100ml distilled water (1)	10ml
Amount of soil after standing for 24 hours (2)	12ml
% Free Swell : (2-1)*100/1	20.0

Hydrometer tests:

CLIENT:	NatPharm Mutare									
SAMPLE No.:		SPT 01				DATE:			20/3/2017	
MENISCUS CORRECTION (Cm):			1			AIR DRIED MASS (g):			50.0	
DENSITY OF SOIL:			2.32			HYGROSCOPIC MOISTURE FACTOR:			0.97	
% PASSING 2,36mm BS SIEVE:			63.6			TRUE OVEN DRIED MASS:			49.1	

Elapsed Time (t) min	Temp (°C)	Hydrometer Reading (Rh)	Composite Correction (CC)	Corrected Reading (Rh1=Rh-CC)	P% finer than	P1% finer than	Rh - Cm	Effective depth (l) mm	K value from Table 5	Particle Diameter (D) mm
1	25.0	44	5	39	78.6	50.0	43	94	0.01286	0.039
2	25.0	42	5	37	75.4	47.9	41	96	0.01286	0.028
4	25.0	39	5	34	68.4	43.5	38	97	0.01286	0.020
8	25.0	39	5	34	68.4	43.5	38	99	0.01286	0.014
15	25.0	36	5	31	62.4	39.7	35	99	0.01286	0.010
30	25.0	36	5	31	62.4	39.7	35	99	0.01286	0.007
60	25.0	33	5	28	56.3	35.8	32	101	0.01286	0.005
120	25.0	29	5	24	48.3	30.7	28	102	0.01286	0.004
240	25.0	29	5	24	48.3	30.7	28	104	0.01286	0.003
1440	25.0	29	5	24	48.3	30.7	28	104	0.01286	0.001

Parameter	Test Result
Sand fraction	71%
Silt fraction	27%
Coarser Material	2%

CLIENT:	NatPharm Mutare									
SAMPLE No	SPT 02	1.3m				DATE:			21/3/2017	
MENISCUS CORRECTION (Cm) :		1				AIR DRIED MASS (g):			50.0	
DENSITY OF SOIL:		2.37				HYGROSCOPIC MOISTURE FACTOR:			0.96	
% PASSING 2,36mm BS SIEVE:		66.3				TRUE OVEN DRIED MASS:			48.9	

Elapsed Time (t) min	Temp (°C)	Hydrometer Reading (Rh)	Composite Correction (CC)	Corrected Reading (Rh1=Rh-CC)	P% finer than	P1% finer than	Rh - Cm	Effective depth (l) mm	K value from Table 5	Particle Diameter (D) mm
1	24.0	37	3	34	68.8	45.6	36	99	0.01263	0.040
2	24.0	37	3	34	68.7	45.5	36	101	0.01263	0.028
4	24.0	37	3	34	68.7	45.5	36	102	0.01263	0.020
8	24.0	36	3	33	66.7	44.2	35	102	0.01263	0.014
15	24.0	36	3	33	66.7	44.2	35	104	0.01263	0.011
30	24.0	35	3	32	64.7	42.9	34	104	0.01263	0.007
60	24.0	34	3	31	62.6	41.5	33	106	0.01263	0.005
120	24.0	33	3	30	60.6	40.2	32	107	0.01263	0.004
240	24.0	32	3	29	58.6	38.8	31	109	0.01263	0.003
1440	24.0	32	3	29	58.6	38.8	31	111	0.01263	0.001

Parameter	Test Result
Sand fraction	68%
Silt fraction	23%
Coarser Material	7%

CIVILWORKS LABORATORY PRIVATE LIMITED

JOB No. : *Mutare*

CLIENT : *NatPharm*

PROJECT: *Warehouse*

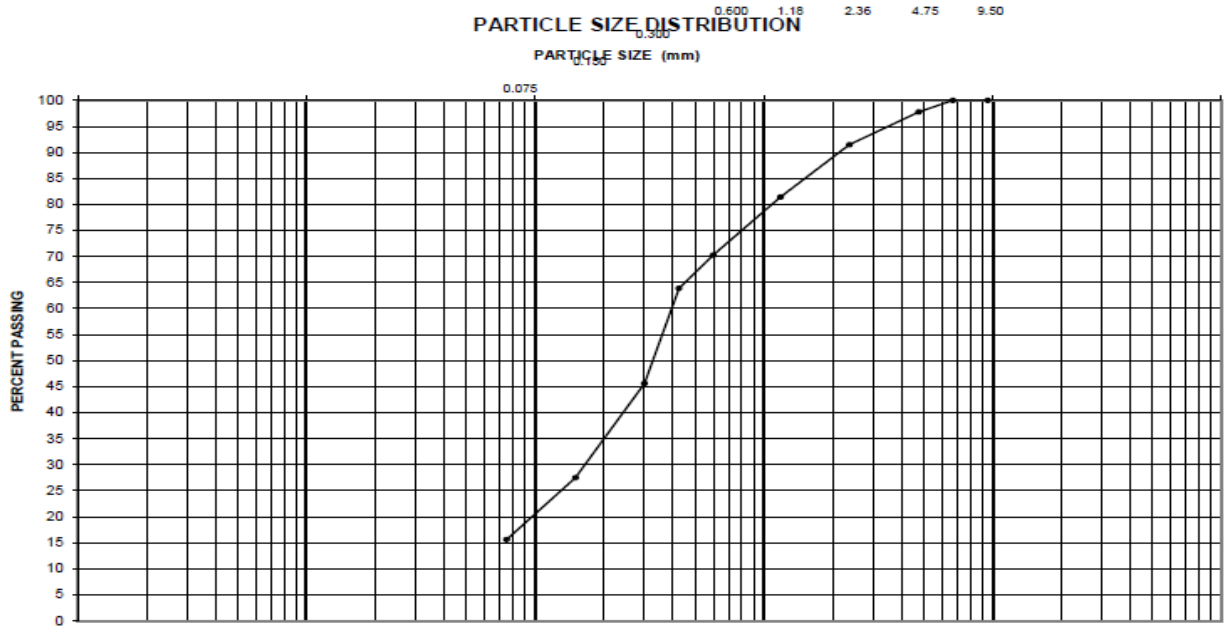
INDICATOR TEST RESULTS SUMMARY SHEET

TRIAL PIT No.		1	2	3	SPT 1	SPT 3
LAB. TEST No.		109/17	110/17	111/17	112/17	113/17
LOCATION	(CH)					
DEPTH	(mm)	350 - 700	900 - 1 700	1 340 - 3 280	1 200	600
BS SIEVE SIZE (mm)		**PERCENTAGE PASSING**				
37.5						
26.5						
19.0		100	100	100	100	
9.5		97	99	100	98	100
4.75		96	98	99	95	99
2.36		94	95	95	90	88
1.18		88	88	78	75	78
0.600		69	71	60	72	61
0.300		44	47	45	64	41
0.150		36	40	39	60	34
0.075		21	26	24	53	22
LIQUID LIMIT	(%)	43	51	18	51	39
PLASTICITY INDEX	(%)	SP	NP	9	11	8
PLASTICITY PRODUCT		0	0	364	588	492
CLASSIFICATION	(AASHTO)	A - 2 - 6	A - 2 - 6	A - 2 - 6	A - 2 - 6	A - 1 - B
M.D.D.	(kg/m^3)	0	0	0	0	0
O.M.C.	(%)	0	0	0	0	0
C.B.R. @ 93%	(%)	0	0	0	0	0
C.B.R. @ 95%	(%)	0	0	0	0	0

NAME : *Rich Sithole*

DATE : *26-Mar-17*

Appendix 6 Sieve Analysis Tests Sheets



SAMPLE CHARACTERISTICS

GEOLOGICAL ORIGIN: GRANITIC SAND

SAMPLE DESCRIPTION: 350 - 400

DRY COLOUR: ~~WHITE CREAM FAWN YELLOW ORANGE RED~~ BROWN ~~OLIVE GREY BLACK~~

ESTIMATED MICA CONTENT: ~~VERY HIGH HIGH MEDIUM~~ LOW ~~NIL~~

ESTIMATED ORGANIC CONTENT: ~~VERY HIGH HIGH MEDIUM~~ LOW ~~NIL~~

AGGRAGATE SHAPE: ~~SUB ROUNDED SUB~~ ANGULAR IRREGULAR ~~FLAKY ELONGATED~~

AGGREGATE SURFACE TEXTURE: ~~GLASSY SMOOTH~~ GRANULAR ROUGH ~~HONEYCOMBED~~

AGGREGATE HARDNESS: SOUND HARD ~~FRACTURED BRITTLE~~ SOFT

INDICATOR RESULTS

LIQUID LIMIT: _____ (%) PLASTICITY INDEX: 0 (%) FINENESS INDEX: _____ (%)

PLASTICITY PRODUCT: _____ COARSENESS INDEX: _____ (%) REJECT INDEX: _____ (%)

TREATMENT

UNSTABILISED ~~STABILISED~~ STABILISER: ~~LIME CEMENT~~ AMOUNT: NIL (%)

COMPACTION DETAILS

COMPACTIVE EFFORT: L C E ~~I C E H C E MOD AASHTO PROCTOR~~

MAXIMUM DRY DENSITY: _____ (kg/m^3) OPTIMUM MOISTURE CONTENT: _____ (%)

C B R DETAILS

CBR AT OMC: _____ (%) EXPANSION AT OMC: _____ (%)

CBR AT (%) H C E / MOD AASHTO: 100: _____ (%) 98: _____ (%) 97: _____ (%)

96: _____ (%) 95: _____ (%) 93: _____ (%) 90: _____ (%)

REMARKS:

NAME: Rich Sithole DATE: 23 March 2017

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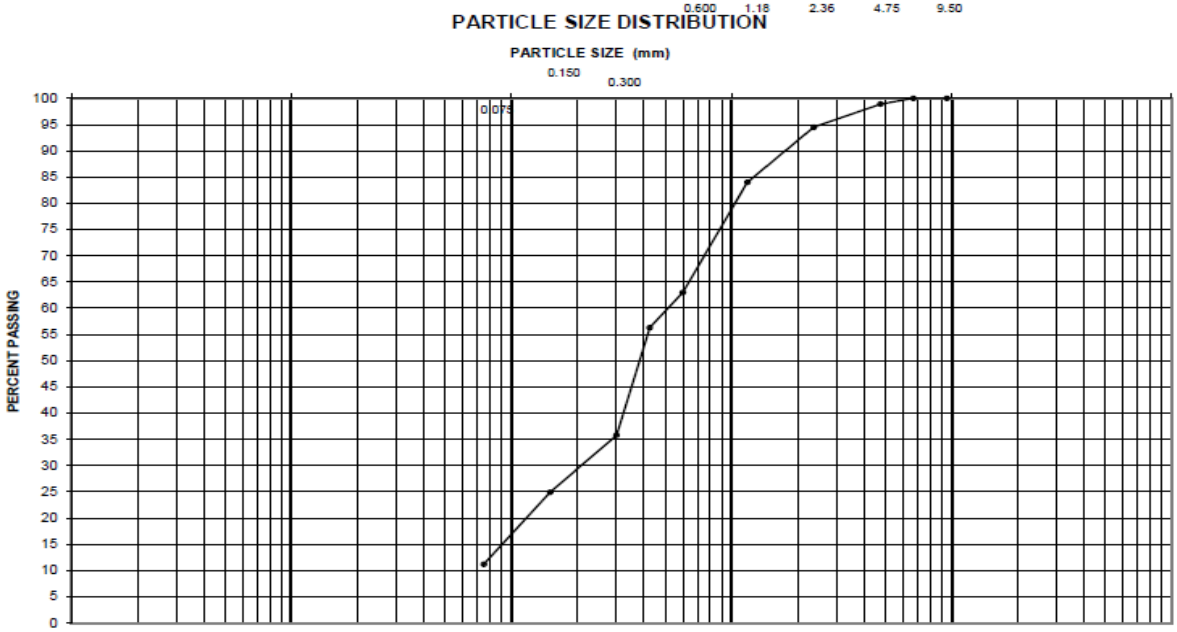
PARTICLE SIZE DISTRIBUTION



SAMPLE CHARACTERISTICS

GEOLOGICAL ORIGIN: GRANITIC SAND

SAMPLE DESCRIPTION: Seam 2.1

DRY COLOUR: ~~WHITE CREAM FAWN YELLOW ORANGE RED~~ BROWN ~~OLIVE GREY BLACK~~

ESTIMATED MICA CONTENT: ~~VERY HIGH HIGH MEDIUM~~ LOW ~~NIL~~

ESTIMATED ORGANIC CONTENT: ~~VERY HIGH HIGH MEDIUM~~ LOW ~~NIL~~

AGGRAGATE SHAPE: ~~SUB ROUNDED SUB~~ ANGULAR IRREGULAR ~~FLAKY ELONGATED~~

AGGREGATE SURFACE TEXTURE: ~~GLASSY SMOOTH~~ GRANULAR ROUGH ~~HONEYCOMBED~~

AGGREGATE HARDNESS: SOUND HARD ~~FRACTURED BRITTLE~~ SOFT

INDICATOR RESULTS

LIQUID LIMIT: 0 (%) **PLASTICITY INDEX:** 0 (%) **FINENESS INDEX:** 24.9 (%)

PLASTICITY PRODUCT: 0 **COARSENESS INDEX:** 55 (%) **REJECT INDEX:** 0 (%)

TREATMENT

UNSTABILISED ~~STABILISED~~ **STABILISER:** ~~LIME CEMENT~~ **AMOUNT:** NIL (%)

COMPACTION DETAILS

COMPACTIVE EFFORT: L C E ~~I C E H C E MOD AASHTO PROCTOR~~

MAXIMUM DRY DENSITY: 1590 (kg/m^3) **OPTIMUM MOISTURE CONTENT:** 11.6 (%)

C B R DETAILS

CBR AT OMC: 29 (%) **EXPANSION AT OMC:** _____ (%)

CBR AT (%) H C E / MOD AASHTO: **100:** _____ (%) **98:** _____ (%) **97:** _____ (%)

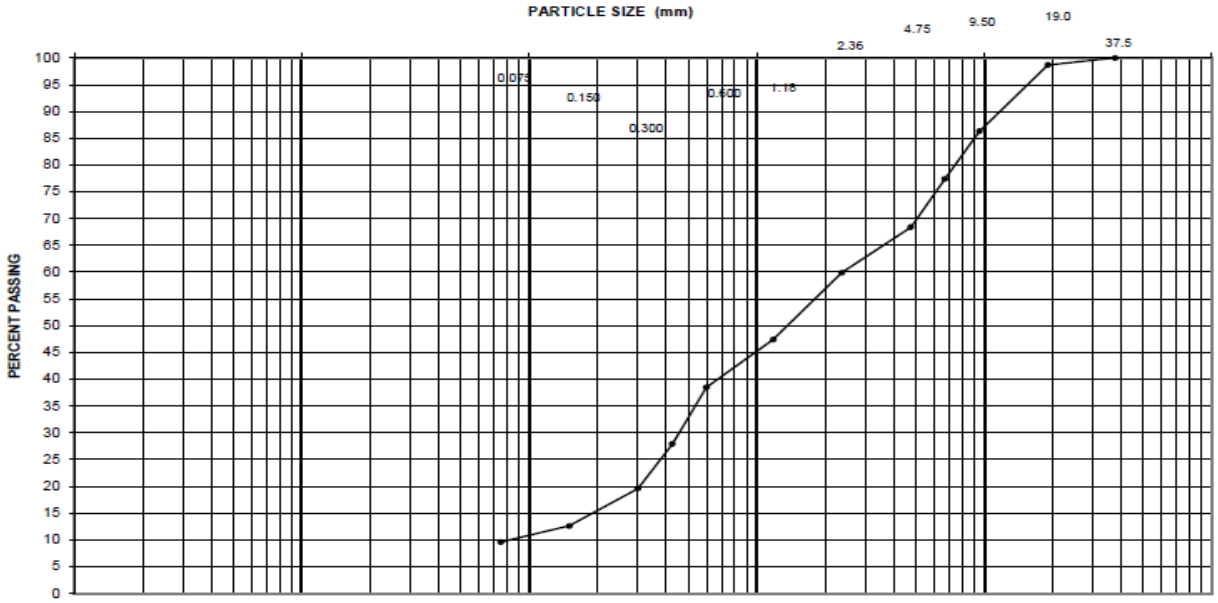
96: _____ (%) **95:** _____ (%) **93:** _____ (%) **90:** _____ (%)

REMARKS:

NAME: T. Sibanda **DATE:** 22 April 2017

Empowered lives.
Resilient nations.

PARTICLE SIZE DISTRIBUTION



SAMPLE CHARACTERISTICS

GEOLOGICAL ORIGIN: QUARTZ

SAMPLE DESCRIPTION: SEAM (400 - 900)

DRY COLOUR: ~~WHITE CREAM FAWN YELLOW ORANGE RED~~ BROWN ~~OLIVE GREY BLACK~~

ESTIMATED MICA CONTENT: ~~VERY HIGH HIGH MEDIUM~~ LOW ~~NIL~~

ESTIMATED ORGANIC CONTENT: ~~VERY HIGH HIGH MEDIUM~~ LOW ~~NIL~~

AGGREGATE SHAPE: ~~SUB ROUNDED SUB~~ ANGULAR IRREGULAR ~~FLAKY ELONGATED~~

AGGREGATE SURFACE TEXTURE: ~~GLASSY SMOOTH~~ GRANULAR ROUGH ~~HONEYCOMBED~~

AGGREGATE HARDNESS: SOUND HARD ~~FRACTURED BRITTLE~~ SOFT

INDICATOR RESULTS

LIQUID LIMIT: _____ (%) PLASTICITY INDEX: _____ (%) FINENESS INDEX: _____ (%)

PLASTICITY PRODUCT: _____ COARSENESS INDEX: _____ (%) REJECT INDEX: _____ (%)

TREATMENT

UNSTABILISED ~~STABILISED~~ STABILISER: ~~LIME CEMENT~~ AMOUNT: NIL (%)

COMPACTION DETAILS

COMPACTIVE EFFORT: L C E ~~I C E H C E MOD AASHTO PROCTOR~~

MAXIMUM DRY DENSITY: _____ (kg/m^3) OPTIMUM MOISTURE CONTENT: _____ (%)

C B R DETAILS

CBR AT OMC: _____ (%) EXPANSION AT OMC: _____ (%)

CBR AT (%) H C E / MOD AASHTO: 100: _____ (%) 98: _____ (%) 97: _____ (%)

96: _____ (%) 95: _____ (%) 93: _____ (%) 90: _____ (%)

REMARKS:

NAME: Rich Sithole DATE: 26 March 2017

Appendix 7 Project photos

Figure 1 the granitic hill on the north western end of the vacant stand.

Figure 2 Dark grey overburden and next horizon of pit sand.

Figure 3 Pit sand as the 2nd horizon in trial pi no: 02

Figure 4 seasonal water table at approximately one meter below natural ground level in all trial pits excavated.

Figure 5 the SPT assemble.

Figure 6 there are two gullies in the vacant stand. The deepest is approximately 1.3m and twenty meters long.

Appendix 8 Table of references

Item	Standard Test Procedure No: Part N	Test Description	As read with CAS No:
1	STP. 705	Standard Penetrometer Test	CAS No: A43, part 2
2	STP. 706	Dynamic Cone Penetrometer	
3	STP. 710	Free Swell Test	
4	STP. 3	Sieve analyses	
5	STP. 4	Determination of % Moisture Content	
6	STP. 6	Determination of Liquid Limit	
7	STP. 7	Determination of Plastic limit	
8	STP. 9	Determination of Linear Shrinkage	CAS No: 185. Part 1: 1977
9	STP. 13	Determination of Max ϒD (Mod AASHTO Method T99)	
10	STP. 20	Determination of California Bearing Ratio	
11		Determination of soil Permeability tests	ASTM D6391 - 11
12		Determination of Shear tests	BS 1377 – 7 - 1990

Tests methods references

B.S. 1377 - Methods of testing soils for civil engineering purposes.

CAS No. A 43 - Parts 1 and 2, Methods of testing soils for civil engineering purposes.

A.S.T.M. D 422 - Grain size analysis of soils.

4.2.1. Insitu Materials Survey (Soil Survey)(Method No. M.P.M. 2/2)

4.2.1.1. General

Insitu materials surveys are normally undertaken along pegged and referenced road lines where chainage points have been placed at 40 metre intervals consecutively, commencing from a datum Ch. 00 + 000. There are normally three pegs at each chainage point, one on the centre line and the others on the edges of the road servitude, these being marked "L" for left and "R" for right. All materials surveys shall be referenced to these chainage points, e.g. a trial hole sunk at chainage 108 + 000 shall be numbered "Hole No. 108.000".

Before any insitu materials survey is commenced, notification of persons having rights in the land must be completed in accordance with Section 3 of this Manual.

4.2.1.2. Preliminary

The marked up airphotos for the proposed project must first be obtained from the Materials Planning Division. These will indicate Parent Material Type, areas of suspect drainage and areas where highly active soil can be expected. (See Section 4.2.7(a)). Often they will indicate exactly how and where sampling should take place.

4.2.1.3. Position of Trial Holes

If not specifically indicated on the airphotos the holes shall follow a set pattern and shall be excavated along the centre line, at intervals of 80 m (commencing normally with the datum peg) or at every change of material along the line, whichever shall be lesser. Where transverse changes occur, as many holes shall be dug as are necessary to give complete coverage of all such lateral variations. Great care must be exercised to ensure that the surveyor's pegs are not disturbed, damaged, or covered with soil from the holes; to this end, no hole shall be dug within a 3 m radius of any surveyor's peg.

4.2.1.4. Size and Depth of Holes

To facilitate digging and sampling, holes shall be dug to a minimum size of 1 m long by 0,5 m wide and a minimum depth of 1 m in level ground; all sides shall be vertical. Over sections of the line where extensive deep cut is anticipated or where features necessitate special subsoil investigations, special trial holes shall be dug: [illegible] investigated by teams from M.P.D. using

4.2.1.6. Other Information

Whether the survey is dictated by the markings on the airphoto or whether it is following the 80 m pattern, the road line shall be walked and the following information recorded.

Page 68 paragraph c (sampling & testing of samples)

(c) At least one full test shall be carried out for each material type. Where any horizon appears to remain unchanged for a considerable length, one sample for indicator tests shall be taken at intervals not exceeding 300 m. After completion of indicator tests, all samples shall be retained until authority is received to dispose of them.

Appendix 9 – Boreholes lay out plan

Summary of Findings:

1. The geological origin of the soil profile from natural ground level is:-
    I. Humus granitic sand (overburden).
    II. Granitic sand (seam)
    III. Quartz
    IV. Schist
    V. Decomposed granite
2. At proposed founding depth it is schist and decomposed granite. Shearing is not likely.
3. At recommended founding depth, the “N” values ranges from 18 to 22.
4. At proposed founding depth, the insitu soil bearing capacity is 110kpa to 200kpa.These are incremental with depth.
5. No water table was noticed in the three boreholes drilled. Only seasonal water table was encountered approximately one meter depth from natural ground level.

Recommendations:

1. Recommendation is made to found at an insitu soil bearing capacity greater than 110kpa. Whilst this is generally lower than the minimum of 150kpa which will be expected for such structures, this is compensated by the preferred type of foundation that is the pad (column/stub). Bases should be widened.
2. Recommendation is made to pre-collapse the insitu soil at proposed founding depth to a minimum effective thickness of 450mm.
3. Recommendation is made to excavate to found from two meter depth from natural ground level to two and half meters at most.

4. Due to the terrain, it is recommended to step the foundation of the warehouse. Terracing could be necessary.
5. Recommendation is made to use the insitu excavated material which can be mechanically blended with imported inert granular material to be used as hardcore backfill. Lay the hardcore layers in 150mm thick compacted to 96% Mod AASHTO.
6. Recommendation is made, that, the last three 150mm layers of hardcore to be of G6 or better imported material and chemical stabilized to C3 or better and compacted to 98% Mod ASSHTO (refer to COLTO table 3402/1 and table 3402/5).

MARCH 2017

Prepared by: -

(CIVILWORKS – GEOTECHNICAL CONSULTANT) DATE

Reviewed by: -

(Min. of Public Works & National Housing – Project Team) DATE

Checked by:-

(– PROJECT ENGINEER) DATE

Recommended:-

(– GENERAL MANAGER) DATE

Recommended:-

( ) DATE